REVISED FINAL
GEOTECHNICAL INVESTIGATION
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
HOUSTON, TEXAS
CSJ NO. 0912-71-739
WBS NO. N-000686-0002-3

SUBMITTED TO
AECOM
5444 WESTHEIMER RD, SUITE 200
HOUSTON, TEXAS 77056

BY
HVJ ASSOCIATES, INC.
HOUSTON, TEXAS
DECEMBER 16, 2015 (REVISION 3)

REPORT NO. HG0519680
KEY MAP NOS. 373R, 374N & 374P

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December 16, 2015

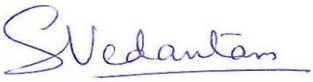
Mr. Ryan Quinn, PE
AECOM
5444 Westheimer Rd, Suite 200
Houston, Texas 77056

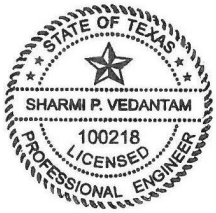
Re: Geotechnical Study
Greens Road from Aldine Westfield to JFK
Houston, Texas
Owner: City of Houston and Texas Department of Transportation
HVJ Project No. HG0519680

Dear Mr. Quinn:

Submitted herein is the revised final report of our geotechnical investigation for the above referenced project. Revisions were made to incorporate the HCFCD comments. The study was conducted in general accordance with our proposal number HG0519680 August 31, 2005 (Revised October 9, 2013) and is subject to the limitations presented in this report. We appreciate the opportunity of working with you on this project. Please read the entire report and notify us if there are questions concerning this report or if we may be of further assistance.

Sincerely,
HVJ ASSOCIATES, INC.
Texas Firm Registration No. F-000646





Sharmi P. Vedantam, PE
Project Manager - Geotechnical 12/16/2015

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This document was authorized by Sharmi P. Vedantam, PE 100218 and Gina Ellison, PE 109846 on December 16, 2015. The geotechnical investigations presented in Sections 3 thru 11 and 13 were completed under the direction of Mrs. Vedantam; the pavement recommendations presented in Section 12 were developed by Mrs. Ellison. Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act.

The following lists the pages which complete this report:

- Main Text – 40 pages
- Plates – 14 pages
- Appendix A – 26 pages
- Appendix B – 5 pages
- Appendix C – 21 pages
- Appendix D – 2 pages
- Appendix E – 3 pages
- Appendix F – 3 pages
- Appendix G – 5 pages
- Appendix H – 5 pages
- Appendix I – 5 pages
- Appendix J – 2 pages
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- Appendix M – 33 pages
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- Appendix Q –2 pages
- Appendix R – 3 pages
- Appendix S – 27 pages

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PLATES

APPENDICES

1 EXECUTIVE SUMMARY

The purpose of this study is to provide design and construction recommendations for the proposed underground utilities, culvert, bridge foundation, detention pond, and pavement associated with the Greens Road improvements from Aldine Westfield to JFK in Houston, Texas. Based on the subsurface conditions revealed by the soil borings, the findings and recommendations of this report are summarized below:

1. Cohesive soils were generally encountered in all the borings drilled for this study. Notably, Boring B-14 consists of clayey sand (SC) layers from the bottom of the pavement to El. 75.0 feet and from El. 70.0 to El. 60.0 feet.

2. Based on our desktop fault study, faulting is not anticipated to impact the project site. However, unmapped faults may exist near the project site. A detailed fault study is not within the scope of this study.

3. Based on the piezometer readings, we expect groundwater at elevations ranging from 73 to 60 feet throughout the project alignment.

4. Recommendations for replacement of utilities using open cut techniques are presented in Section 6 of this report.

5. Drilled shaft and driven pile capacities were calculated at boring locations BR-1 and BR-2 using the procedures described in the Texas Department of Transportation Geotechnical Manual dated December, 2012 and are presented in Appendix H and Appendix I, respectively.

6. The proposed cross section provided by AECOM for the detention basin is safe. The slope stability analysis results are presented in Appendix M of this report. The results of our analysis are summarized in the table below.

Detention Pond Slope	**Global Stability**		
	End of Construction	**Long Term**	**Rapid Drawdown**
4H:1V	7.1	2.0	1.8

7. The proposed cross section provided by AECOM for the Hoods Bayou is safe. The slope stability analysis results are presented in Appendix S of this report. The results of our analysis are summarized in the table below.

Bayou Slope	**Global Stability**		
	End of Construction	**Long Term**	**Rapid Drawdown**
2H:1V	3.7	1.5	1.3

8. Recommendations for the extension of the existing Box Culvert at Old Hoods Bayou are presented in section 9 of this report.

9. The pavement was cored at coring locations C-1 to C-10 and the pavement thickness information was obtained. The pavement thicknesses at coring locations are 3 inches to 6 inches of Hot Mix Asphalt Concrete over 5 inches to 10 inches of Cement Stabilized Shells.

10. DARWin was used to run rigid pavement alternatives for a 30-year and 50-year design life for Greens Road. The recommended design for Greens Road for 30-year design is 10" Jointed Reinforced Concrete Pavement over 8" Lime Stabilized Subgrade and for 50-year design it is 11.5" Jointed Reinforced Concrete Pavement over 8" Lime Stabilized Subgrade. The detailed design is discussed in Section 11.

Please note that this executive summary does not fully relate our findings and opinions. Those findings and opinions are only presented through our full report.

2 INTRODUCTION

2.1 Project Description

HVJ Associates, Inc. was retained by AECOM to provide geotechnical and pavement recommendations for the improvement of Greens Road from Aldine Westfield to JFK in Houston, Texas. The project alignment is approximately 1.6 miles. The improvements include the following:

- Widening of Greens Road by extending the right of way towards the north on the portion of Greens Road that is east of Hoods Bayou, and by extending the right of way towards the south on the portion of Greens Road that is west of Hoods Bayou.
- Replacing underground utilities using open cut technique.
- Pavement replacement along Greens Road.
- Constructing a bridge crossing at Hoods Bayou.
- Extending the existing culvert at Old Hoods Bayou.
- Constructing a detention pond adjacent to Payton Street.

2.2 Geotechnical Investigation Program

The major objectives of this study were to gather information on subsurface conditions at the site and to provide design and construction recommendations for the proposed underground utilities, culvert, bridge foundation, detention pond, and pavement improvements. The field work and design for utilities, bridge, culvert and pavement borings was performed in accordance with Texas Department of Transportation Geotechnical Manual dated December 01, 2012. The field work and design for detention pond borings was performed in accordance with Harris County Flood Control District Geotechnical guidelines dated December 21, 2010. The objectives were accomplished by:

- Drilling nineteen (19) soil borings to depths between 25 and 80 feet below the existing grade to determine soil stratigraphy and to obtain samples for laboratory testing.

- Coring ten (10) pavement cores to obtain pavement thickness.

- Installing four (4) piezometers to gain an understanding of the groundwater conditions at the site and to evaluate the potential need for dewatering during construction.

- Performing laboratory tests to determine physical and engineering characteristics of the soils.

- Performing engineering analyses to develop design guidelines and construction recommendations for the proposed underground utilities, culvert, bridge foundation, detention pond, and pavement improvements.

Subsequent sections of this report contain descriptions of the field exploration, laboratory-testing program, general subsurface conditions, design recommendations, and construction considerations.

3 FIELD INVESTIGATION

3.1 Geotechnical Borings

The field exploration program undertaken at the project site was performed between July 28, 2014 and August 08, 2014. Subsurface conditions were investigated by drilling nineteen (19) soil borings

to a depth ranging between 25 and 80 feet below the existing grade. The field exploration program is summarized in Table 3-1.

Table 3-1 Field Exploration Program

Boring	Depth (ft)	Structure
BR-1	80	Bridge, Utility lines, and Pavement Boring
BR-2	80	Bridge, Utility lines, and Pavement Boring
DP-1	25	Detention Pond Boring
DP-2	25	Detention Pond Boring
DP-3	25	Detention Pond Boring
B-1	28	Culvert, Utility lines and Pavement Boring
B-2	28	Utility lines, and Pavement Boring
B-3	28	Utility lines, and Pavement Boring
B-4	28	Utility lines, and Pavement Boring
B-5	28	Utility lines, and Pavement Boring
B-6	28	Utility lines, and Pavement Boring
B-7	28	Utility lines, and Pavement Boring
B-8	28	Utility lines, and Pavement Boring
B-9	28	Utility lines, and Pavement Boring
B-10	28	Utility lines, and Pavement Boring
B-11	28	Utility lines, and Pavement Boring
B-12	28	Utility lines, and Pavement Boring
B-13	28	Utility lines, and Pavement Boring
B-14	28	Utility lines, and Pavement Boring

All boreholes excluding the ones with piezometers were backfilled with cement grout by tremie method in accordance with the City Guidelines and patched at the surface where applicable. The piezometers will be plugged after obtaining the 30 day water level readings. Approximate boring and coring locations are presented on Plate 2 of the report.

3.2 Survey Data

The survey data of borings were provided to us by AECOM and are presented in Table 3-2 below.

Table 3-2 Borehole Survey Data

Boring	Station (feet)	Northing (feet)	Easting (feet)	Offset (feet)	Elevation (feet)
B-1	31+34.19	13912510.26	3123900.16	2.85 LT	77.24
B-2	26+54.69	13912478.39	3123421.65	5.36 RT	76.65
B-3	21+06.42	13912450.44	3122874.09	6.23 RT	77.35
B-4	16+46.01	13912438.05	3122413.73	4.13 LT	78.90
B-5	42+32.97	13912563.21	3124997.67	1.54 LT	77.28
B-6	48+29.73	13912610.50	3125592.82	19.39 LT	78.11
B-7	53+01.06	13912607.01	3126064.90	7.41 RT	78.41
B-8	57+32.87	13912636.64	3126495.77	0.90 LT	79.41
B-9	62+89.31	13912682.38	3127050.63	19.19 LT	79.71
B-10	67+47.50	13912676.25	3127509.68	9.59 RT	78.99
B-11	72+79.16	13912730.35	3128039.31	18.29 LT	80.29

Boring	Station (feet)	Northing (feet)	Easting (feet)	Offset (feet)	Elevation (feet)
B-12	77+55.24	13912732.79	3128515.84	0.29 LT	80.62
B-13	82+55.12	13912781.31	3129014.15	28.24 LT	80.23
B-14	87+67.43	13912792.42	3129526.44	18.23 LT	80.47
BR-1	37+65.83	13912557.74	3124530.22	19.16 LT	77.17
BR-2	36+39.50	13912534.80	3124404.87	2.43 LT	76.73
DP-1	33+90.29	13911533.02	3124204.88	988.24 RT	74.51
DP-2	34+84.38	13911544.10	3124298.54	981.80 RT	74.84
DP-3	35+66.60	13911548.88	3124380.63	981.08 RT	74.08

Coordinates shown are referenced to U.S. State Plane Texas South Central Zone, North American Datum 83. Elevations are referenced to North American Vertical Datum (NAVD) 88.

3.3 Sampling Methods

Culvert, Bridge, Utility lines and Pavement Borings

Cohesive soil samples were obtained continuously using a 3-inch diameter thin walled tube pushed into soil in general accordance with the ASTM D1587 standard. Granular cohesionless soils were sampled in accordance with the ASTM D1586 standard. Each sample was removed from the sampler in the field, carefully examined and then classified using the Visual-Manual Procedure for Description and Identification of Soils in accordance with TxDOT Test Method Tex-141-E. The shear strength of the cohesive soils was estimated by TxDOT cone penetrometer in the field. Suitable portions of each sample were sealed and packaged for transportation to our laboratory.

The TxDOT cone penetrometer test was performed at approximately 5-foot intervals. The TxDOT cone test is used to determine the relative density or consistency of a soil material. The test consists of driving a 3-inch diameter cone with a 170-pound hammer, which is dropped for a distance of 2 feet. Then it is driven for two consecutive 6-inch increments, and the blow counts for each increment are noted. In hard materials, the cone is driven with the resulting penetration in inches recorded for the 50 blows. The number of blows for each 6-inch increment and/or the amount of penetration for each 50 blows is presented on the boring logs presented in Appendix A. A key to the soils classification and symbols used in the boring logs is also presented in Appendix A.

Detention Pond Borings

Soil samples were obtained continuously to a depth of 20 feet and at 5-foot intervals thereafter to the termination depth of the borings. Cohesive soil samples were obtained with a three-inch thin-walled (Shelby) tube sampler in general accordance with ASTM D-1587 standard. Each sample was removed from the sampler in the field, carefully examined, and then classified. The shear strength of the cohesive soils was estimated by a hand penetrometer in the field. Cohesionless soils were sampled with the split spoon sampler in accordance with ASTM D 1586 standard. Suitable portions of each sample were sealed and packaged for transportation to our laboratory.

Detailed descriptions of the soils encountered in the borings are given on the boring logs presented in Appendix A. A key to the soils classification and symbols used in the boring logs is also presented in Appendix A.

3.4 Pavement Thickness Measurements

The pavement was cored at coring locations C-1 to C-10 and the pavement thickness information was obtained. The pavement thickness at coring locations C-1 to C-10 is presented in the Table 3-2.

Table 3-3 Pavement Thickness Data

Boring No.	Coring No.	Asphaltic Concrete Thickness (inches)	Cement Stabilized Shells Base Thickness (inches)
BR-2	C-1	3"	10"
BR-1	C-2	3"	10"
B-5	C-3	6"	7"
B-6	C-4	5"	6"
B-8	C-5	5"	7"
B-9	C-6	5"	5"
B-11	C-7	5"	6"
B-12	C-8	5"	6"
B-14	C-9	4"	6"
B-1	C-10	5"	7"

3.5 Water Level Measurements

Groundwater was measured at all boring locations during drilling operations. Four piezometers were installed at boring locations B-4 (PZ-1), B-7 (PZ-2), B-13 (PZ-3) and DP-2 (PZ-4) to obtain the 24-hour, 15-day and 30-day water level readings. The piezometer set-up consists of 2-inch (PZ-1 through PZ-3) or 3-inch (PZ-4) PVC screen surrounded by 20/40 sieve filter pack sand below a 2-inch diameter PVC riser which is surrounded by hydrated bentonite pellets. The installed piezometers were flush mounted with steel covers and surrounded in 4-foot by 4-foot by 2-inch concrete pads. During plugging or abandonment, all the components of the installed piezometers are pulled out and the hole is filled with bentonite pellets/cement slurry to restore the site. Piezometer installation records and groundwater level data are provided in Appendix C. Piezometer "Well Reports" and "Plugging Reports" are also provided in Appendix C.

4 LABORATORY TESTING

Selected soil samples were tested in the laboratory to determine applicable physical and engineering properties. All tests were performed according to the relevant ASTM Standards. These tests consisted of moisture content measurement, percent passing No. 200 sieve, Atterberg limits, unconsolidated undrained compression and unit dry weight tests.

The Atterberg Limits and percent passing number 200 sieve tests were utilized to verify field classification by the Unified Soils Classification System, and the unconsolidated undrained compression tests was performed to obtain the undrained shear strength of the soil. The type and number of tests performed for this investigation are summarized below:

Table 4-1 Type and Number of test Performed

Type of Test	Number of Tests
Moisture Content (ASTM D2216)	100
Atterberg Limits (ASTM D4318)	67
Percent Passing No. 200 Sieve (ASTM D1140)	69
Sieve Analysis and Hydrometer (ASTM D422)	2

Type of Test	Number of Tests
Unconsolidated Undrained Triaxial (ASTM D2850)	58
Consolidated Undrained Triaxial (ASTM D4767)	2
Pinhole Test (ASTM D4647)	2
Crumb Test (ASTM D6572)	4
Lime Series Test (ASTM D6276)	1

The laboratory test results are presented on the boring logs in Appendix A. A summary of laboratory test results is provided in Appendix B. Crumb test results are presented in Appendix D. Pinhole test results are presented in Appendix E. Consolidated undrained test results are presented in Appendix G.

4.1 Sieve Analysis and Hydrometer Tests Results

Two sieve and hydrometer analysis were conducted on samples obtained from Hoods Bayou to obtain the diameter of 50 percent (D_{50}) passing. The test results are summarized in the Table 4-2 below. The test results are presented in Appendix F.

Table 4-2 Sieve and Hydrometer Analysis

Sample	Borings in the Vicinity	Approx. Depth (feet)	D_{50} (mm)
Hoods Bayou Slope	BR-1 and BR-2	15	0.047
Hoods Bayou Bottom	BR-1 and BR-2	25	0.045

4.2 Lime Series Test

HVJ performed one pH (ASTM D6276) lime series test on the composite sample obtained from pavement borings which exhibited fat clay at 2 to 4 feet depth below existing grade. Based on the lime series test results, 6% lime per dry unit weight appears to be an adequate estimate for stabilization of the onsite clays to perform satisfactorily as pavement subgrade. The lime series test results are presented in Appendix P.

5 SITE CHARACTERIZATION

5.1 General Geology

There are two major surface geological formations that exist in the Houston area: the Beaumont formation and the Lissie formation. The Beaumont formation is a relatively younger formation generally found to the southeast of the Lissie formation. The Beaumont formation dips southeastward and extends beneath beach sand and waters of the Gulf of Mexico as far as the continental shelf. The project alignment is located in the Lissie formation. A geologic map is presented on Plate 3.

The Lissie formation is heterogeneous, containing interbedded layers of clay, sand and silt. It was deposited in mid-Pleistocene times in shallow coastal river channels and flood plains. The coastal plain in this region has a complex tectonic geology, several major features of which are: Gulf Coastal geosyncline, salt domes, major sea level fluctuations during the glacial stages, subsidence and faulting. Most faulting have ceased for millions of years, but some faults are still active.

5.2 Geologic Faulting

The tectonic history of the Texas Gulf Coast includes a relatively stable depositional cycle since the Cretaceous Period (about 65 million years). During this period the area was subjected to deposition of clays, silts, and sands resulting in over 30 thousand feet of sedimentary rocks. Underlying this

clastic sequence are salt formations, which have migrated upwards to produce the typical salt dome features associated with the Texas Gulf Coast. In conjunction with salt movement, dewatering and compaction of some of the deeper sediments in the basin have resulted in the development of growth faults.

A literature review of surface faults near the project area was conducted based on the Bureau of Economic Geology, University of Texas at Austin, Geologic Atlas of Texas Houston Sheet, Paul Weaver Memorial Edition (revised in 1982). The primary objective of this review was to evaluate available information from published and open file reports. Based on our review, the project site is located approximately 1-3 miles south west of a couple of unnamed faults. Faulting is not anticipated to impact the project site. However, unmapped faults may exist near the project site. A detailed fault study is not within the scope of this study. A fault map is presented in Plate 4 of this report.

5.3 Soil Stratigraphy

HVJ's interpretation of soil and groundwater conditions at the project site is based on information obtained at the boring locations only. This information has been used as the basis for our conclusions and recommendations. Significant variations at areas not explored by the project boring may require reevaluation of our findings and conclusions.

Cohesive soils were generally encountered in all the borings drilled for this study. Notably, Boring B-14 consists of clayey sand (SC) layers from the bottom of the pavement to El. 75.0 feet and from El. 70.0 to El. 60.0 feet.

A generalized summary of the subsurface conditions in our borings is shown in the Table 5-1; it is intended to provide a conceptual framework for considering the site. Substantial deviations from the summarized conditions exist at several boring locations (BR-1 and B-14) and should be accounted for in the design and construction recommendations.

Table 5-1 Generalized Soil Profile

Stratum	Approximate Elevation, Feet		Material
	From	To	
I	Surface	Termination Depth of Borings	Cohesive Soils (CH, CL, CL-ML)

Note:
1. Silty clay with sand (CL-ML) layer was encountered in Boring B-2 from El. 56.2 to El. 48.7 feet and in Boring B-10 from existing grade down to El. 55.0.
2. Boring BR-1 comprised of silt with sand (ML) layers from El. 41.7 to El. 26.7 feet and from El. 21.7 to El. 11.7.
3. Boring B-14 consists of clayey sand (SC) layers from the bottom of the pavement to El. 75.0 feet and from El. 70.0 to El. 60.0 feet.

Details of the subsurface stratigraphy at specific depths encountered in the borings are shown on the boring logs presented in Appendix A. Soil profile plate along the project alignment is presented in Appendix Q.

The Casagrande's Plasticity Chart presented in Figure 5-1 illustrates the range of plasticity of the cohesive soils found during our investigation. Tables 5-2 and 5-3 presents the statistical data for

cohesive soils. Silty clay was not included because of lack of sufficient number of testing to provide reliable results.

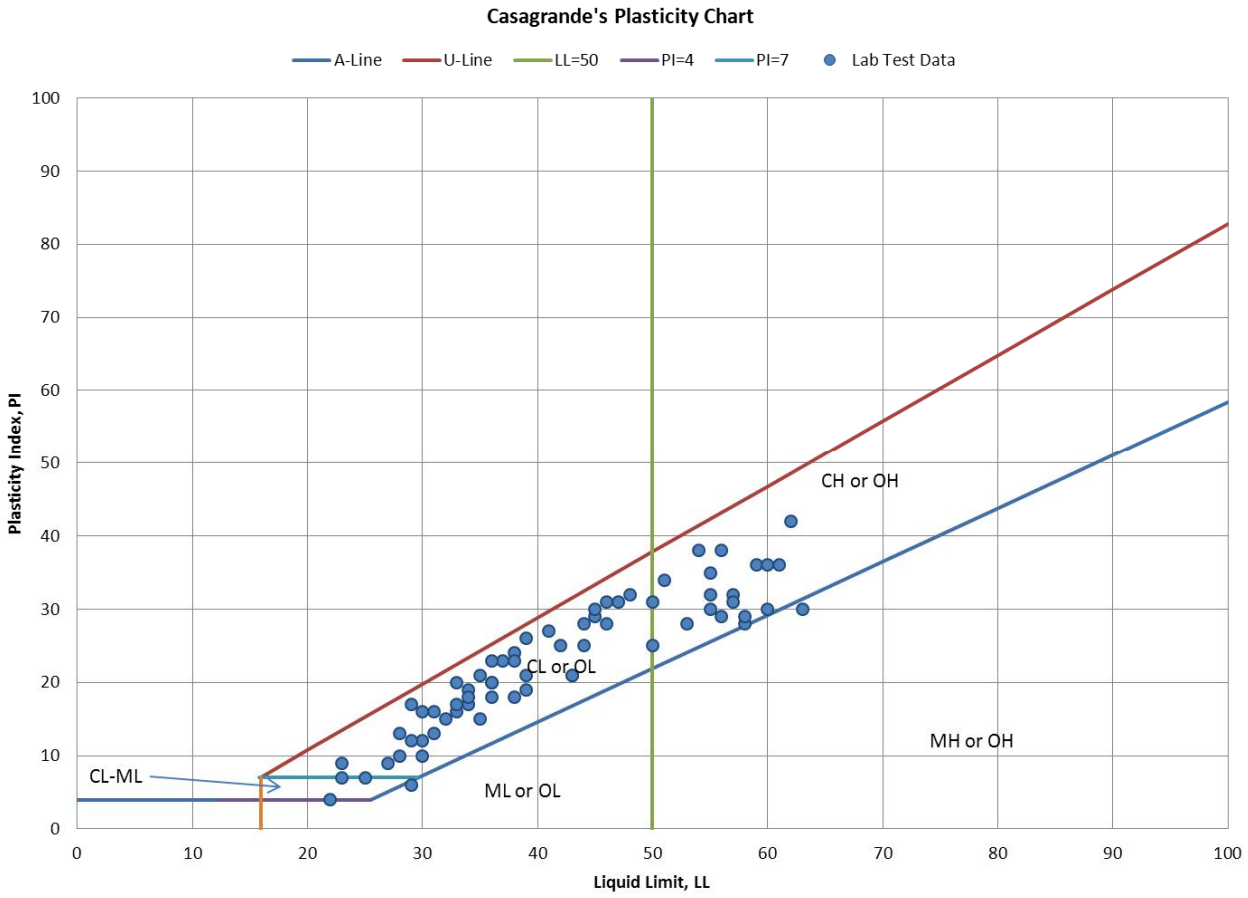


Figure 5-1 Casagrande's Plasticity Chart

Table 5-2 – Statistical Data for Fat Clay

	Liquid Limit (%)	Plasticity Index (%)	% Passing #200 Sieve	Moisture Content (%)	Wet Unit Weight (pcf)	Undrained Shear, UU (psf)
Average	57	33	90	23	130	3070
Maximum	63	42	99	29	137	5292
Minimum	50	25	55	16	119	1253
Standard Deviation	4	4	10	4	5	1124

Table 5-3 – Statistical Data for Lean Clay

	Liquid Limit (%)	Plasticity Index (%)	% Passing #200 Sieve	Moisture Content (%)	Wet Unit Weight (pcf)	Undrained Shear, UU (psf)
Average	37	20	76	18	133	2671
Maximum	48	32	98	29	141	5105
Minimum	23	9	50	12	124	929
Standard Deviation	6	6	12	4	4	1079

5.4 Groundwater Conditions

Groundwater was encountered at borings B-1, B-2, B-3, B-4, B-5, B-6, B-9, B-10, B-11, B-12, B-13, B-14, BR-1 and BR-2 at elevations ranging from 50.1 to 68.5 feet during drilling operations. Four piezometers were installed at boring locations B-4 (PZ-1), B-7 (PZ-2), B-13 (PZ-3) and DP-2 (PZ-4) to obtain the 24-hour, 15-day and 30-day water level readings. Piezometer installation records are provided in Appendix C. Table 5-2 shows a record of the groundwater readings taken during drilling as well as the piezometer readings.

Table 5-4 Groundwater Observations

Boring No.	Groundwater Elevation First Encountered (feet)	Groundwater Reading		
		Groundwater Elevation after 24 Hours (feet)	Groundwater Elevation after 15 Days (feet)	Groundwater Elevation after 30 Days (feet)
B-1	53.2	-	-	-
B-2	56.7	-	-	-
B-3	57.4	-	-	-
B-4 (PZ-1)	53.9	67.1	66.3	66.0
B-5	55.8	-	-	-
B-6	50.1	-	-	-
B-7 (PZ-2)	dry	70.7	68.5	68.0
B-8	dry	-	-	-
B-9	54.7	-	-	-
B-10	54.0	-	-	-
B-11	63.8	-	-	-
B-12	61.6	-	-	-
B-13 (PZ-3)	66.7	73.0	72.8	72.6
B-14	68.5	-	-	-
DP-1	dry	-	-	-
DP-2 (PZ-4)	dry	63.5	61.6	60.2
DP-3	dry	-	-	-
BR-1	53.4	-	-	-
BR-2	52.7	-	-	-

Based on the piezometer readings, we expect groundwater at elevations ranging from 73 to 60 feet below existing ground throughout the project alignment. It should be noted that groundwater levels determined during drilling may not accurately reflect the true groundwater conditions, and therefore should only be considered as approximate. Groundwater levels measured in open standpipe piezometers are, on the other hand are more accurate; however, these readings will fluctuate seasonally and in response to rainfall. Other factors that might impact piezometric groundwater levels include leakage from existing water lines.

6 UTILITY DESIGN CRITERIA AND RECOMMENDATIONS FOR OPEN CUT TECHNIQUES

6.1 General

The project involves the replacement of utility lines associated with Greens Road in Houston, Texas. HVJ's recommendations for the installation of utility lines using open cut techniques are presented below. It is understood that the utilities consist of water lines, sanitary and storm sewers which will be installed by open cut techniques. The invert depth of the utilities will ranges from 7 to 18 feet below the existing grade.

6.2 Geotechnical Parameters

Geotechnical design parameters are presented in Table 6-1. Design parameters given in the table are based on field and laboratory test data obtained at boring locations drilled for utilities at the approximate invert depth. We recommend an allowable bearing capacity of 2500 psf for the utilities embedded on backfill material.

Table 6-1 Utility Design Parameters

Boring No.	Maximum Invert Depth (ft.)	Soil Description at Invert Depth	Total Unit Weight (pcf)	Undrained Shear Strength (psf)	Allowable Bearing Capacity (psf)	E'_n, Long Term (psi)
B-1	18.0	Very Stiff Clay	133	2800	4700	1000
B-2	18.0	Very Stiff Clay	133	2200	3700	1000
B-3	17.0	Very Stiff Clay	127	1200	2000	600
B-4	11.0	Hard Clay	133	4200	6000	2000
B-5	11.3	Very Stiff Clay	134	2400	4000	1000
B-6	11.3	Stiff Clay	130	1800	3000	600
B-7	11.5	Very Stiff Clay	137	4000	6000	1000
B-8	11.8	Very Stiff Clay	141	3000	5100	1000
B-9	12.0	Stiff Clay	131	2000	3400	600
B-10	11.3	Stiff Clay	131	1200	2000	600
B-11	11.7	Stiff Clay	138	1800	3000	600
B-12	11.7	Very Stiff Clay	134	2800	4700	1000
B-13	11.2	Stiff Clay	130	1500	2500	600
B-14	10.6	Very Stiff Clay	135	3200	5400	1000
BR-1	16.0	Stiff Clay	131	1400	2300	600
BR-2	16.0	Very Stiff Clay	136	2400	4000	1000

The values shown in the above table represent HVJ's interpretation of the soil properties based on the available laboratory and field test data. Use of the soil properties shown above may or may not be appropriate for a particular analysis, since choice of design parameters often depends on whether total or effective stress analysis is used, rate of loading, duration of loading, geometry of loaded area, and other factors. The total unit weight values shown above represent our interpretation of soil unit weight at natural moisture content. The undrained shear strength and allowable bearing capacity values represent our interpretation of the shear strength in clay soils based primarily on the results of unconsolidated undrained compression tests and TxDOT cone penetrometer tests. The allowable bearing capacity includes a factor of safety of three.

6.3 Pipe Design

The loads imposed on underground pipes depend principally upon the method of installation, the weight of overburden soils, roadway traffic load, and loads due to existing surface structures. For design of rigid pipes installed using open-cut and trenchless excavation methods, loads due to overburden and traffic can be determined from Plate 7.

The traffic load applied to the rigid pipe can be calculated using 85% of wheel load with an impact factor of 1.5 for one foot of soil cover, 50% of wheel load with an impact factor of 1.35 for 2 feet of cover, and 30% of wheel load with an impact factor of 1.15 for 3 feet of cover. This results in a total design traffic load on the pipe or box culvert of about 1.28, 0.68 and 0.35 times the wheel load for 1, 2 and 3 feet of cover, respectively. For pipes with four or more feet of cover, the traffic loads may be taken as a surcharge equivalent to 250 psf.

Water Line Design: For flexible pipe, overburden pressure can be determined using prism load condition in which overburden pressure is the weight of the column of soil directly over the pipe for the full height of backfill i.e., depth to the spring line of pipe from ground surface times unit weight of soil. The unit weight of soil may be taken as 125 pcf. The traffic load applied to the pipe can be calculated using the equation presented below. The traffic load design provisions described in this section are based on the American Water Works Association (AWWA) Manual M23 (2002) PVC Pipe – Design and Installation and we recommend that the PVC pipe should be designed based on the provisions provided in this manual.

$W_L = P(I_f)/[(L1)(L2)]$

Where:

- W_L: Live load on pipe, psf
- P: Wheel Load, lb
- L1: Wheel contact width w/pavement parallel to the direction of travel + 1.75H, ft
- L2: Wheel contact width w/pavement perpendicular to the direction of travel + 1.75H, ft
- H: Height of soil cover, ft
- I_f: Impact factor
  - 1.1 for 2ft < H < 3 ft
  - 1.0 for H ≥ 3 ft

The design of flexible pipes requires the modulus of soil reaction of the native soil (En') in the trench wall as input. The En' values are based on empirical relationships to the soil consistency as defined by unconfined compression tests for cohesive soils. En' values for the native soils are presented in the table above. The En' values for short-term conditions in cohesive soils may be

assumed to be 1.5 times the long-term values. These values are presented in Table 6-1 and are based on the soil data obtained at the boring locations only and may be used for the noted invert depth zone.

6.4 Open Cut Bedding and Backfill

Bedding and backfill for utilities should be performed in accordance with TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 400. For precast concrete pipes, the excavation should be undercut a minimum depth sufficient to accommodate the class of bedding indicated on the plans and conforming to the bedding requirements. Utilities should be placed as per TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 400.3B. Use Class C bedding details unless otherwise shown on the plans. If cement stabilized backfill is desired for bedding, the excavation should be undercut a minimum of four inches and backfilled with stabilized material to support the pipe at the required grade.

Trench backfill should conform to TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 400.3C. Backfill material may be obtained from excavating on-site soils. On-site soils should be free from stones not more than 4 inches in greatest dimension, free from large lumps, which will not break down readily under compaction; and free from frozen lumps, wood, or other extraneous material. Cement stabilized sand may also be used for backfill and should be in accordance with Item 400.3C4 of TxDOT Standard Specification. After the bedding and pipes have been installed as required, the selected backfill materials shall be brought to proper moisture condition, placed along both sides of the pipe equally, in uniform layers not exceeding eight inches in depth, and each lift thoroughly compacted to at least 95 % of maximum dry density as determined by Tex 114E. Care shall be taken to secure thorough compaction of the materials placed under the haunches of the pipe and to prevent damage or displacement of the pipe. Backfill above the top of the pipe shall be placed and compacted in accordance with Subarticle 400.3C1.

6.5 Thrust Force Design Recommendations

Piping System Thrust Restraint: Unbalanced thrust forces will be developed in water lines due to changes in direction, cross-sectional areas, or when the pipe is terminated. These forces may cause joints to disengage if not adequately restrained. There will be a slight loss of head due to turbulence in bends in the pipes. This loss will cause a pressure change across the bend, but it is usually small enough to be neglected.

The thrust force may require more reaction than is available just from the pipe bearing against the backfill. In order to prevent intolerable movement and overstressing of the pipe, suitable buttressing should be provided. In general, thrust blocks, concrete encasement, restrained joints and tie rods are common methods of providing reaction for the thrust restraint design. Thrust restraint design provisions should be taken in accordance with Chapter 9 on the American Water Works Association Manual M9 (2008) Concrete Pressure Pipe [1] and the American Water Works Association (AWWA) Manual M23 (2002) PVC Pipe – Design and Installation [2].

Frictional Resistance: The unbalanced force produced by grade and alignment changes can also be resisted by friction on the pipe. The length of pipe will be formed by tying or welding joints together for the distance required to develop adequate capacity or by encasing the pipe in concrete. The resisting frictional force, F_R is computed as

$F_R = f\,(2W_e+W_w+W_p)$

Where:

f = Coefficient of friction between pipe and soil

W_e = Weight of soil over pipe in lb/ft

W_w = Weight of contained water in lb/ft

W_p = Weight of pipe in lb/ft

The friction value depends on the material in contact with the pipe and the soil used in the backfill around the pipe. For pipe surrounded by compacted sand or crushed stone, the friction between the pipe and soil may be based on a friction angle of 30 degrees. The allowable coefficient of friction, f, of 0.28, 0.23 and 0.18 can be used for concrete, steel and PVC pipes, respectively. This value includes a factor of safety of 2.0. The weight of soil above the pipe will depend on the soil unit weight and the pipe depth. For compacted soils used for backfill, a total unit weight of 125 pcf can be used.

In low cover situations, where depth of cover is less than 50% of pipe diameter, we should be contacted to evaluate the impact of shallow cover on thrust resistance.

Tied joints are used to transmit thrust across joints. These ties may be welded or harnessed joints. Joints may be welded in the field in order to transmit the thrust involved. Information concerning types of harnessed joints available and size and pressure limitations can be obtained from the pipe manufacturers.

7 UTILITY CONSTRUCTION RECOMMENDATIONS

7.1 General

This section is intended to address issues that might arise during construction. HVJ's recommendations are intended for use as guidelines in dealing with particular soil conditions. The topics addressed in this section include trench excavation stability, groundwater control, and open-cut construction considerations.

The recommendations contained herein are not intended to dictate construction methods or sequences. Instead they are provided solely to assist designers in identifying potential construction problems related to excavation, based upon findings derived from sampling. Depending upon the final design chosen for the project, the recommendations may also be useful to personnel who observe construction activity.

Prospective contractors for the project must evaluate potential construction problems on the basis of their review of the contract documents, their own knowledge of and experience in the local area, and on the basis of similar projects in other localities, taking into account their own proposed methods and procedures.

7.2 Open Cut Excavation Considerations

Excavations should satisfy two requirements. First, the soils above final grade must be removed without disturbing the soil below, which will support constructed facilities. Second, the sides of the

excavation must be stable to prevent damage to adjacent streets and facilities as a result of either vertical or lateral movements of the soil. In addition, a satisfactory excavation procedure must include an adequate construction dewatering system to lower and maintain the water level at least a few feet below the lowest excavation grade.

Excavation Stability. Excavations shall be shored, laid back to a stable slope or some other equivalent means may be used to provide safety for workers and adjacent structures. Earth pressures for braced excavations are presented on Plate 6. Assessment of the need for excavation sloping, use of trench boxes, or other measures required to provide a stable excavation, and the use of appropriate construction practices and/or equipment is the contractor's responsibility. The following comments are intended to represent common solutions to stability problems encountered in similar soil conditions in the Houston area, and may not be construed as excavation system design recommendations. The excavation operations shall be performed in accordance with 29 CFR Part 1926 subpart P, as amended, including rules published in the Federal Register, Vol. 54, No. 209, dated October 31, 1989, as a minimum. In addition, the provisions of legislation enacted by the Texas legislature and conformance to TxDOT Standard Specifications for Construction of Highways, Streets, and Bridges, Item 402 and 403 should be satisfied. Table 7-1 shows the classification of soils for excavations according to OSHA standards.

Table 7-1 OSHA Soil Type

Boring No.	OSHA Soil Type			
	Depth of Trench (ft.)			
	0 – 5	5 – 10	10-15	15 – 20
B-1	B	B	B	B
B-2	B	B	B	B
B-3	B	B	B	B
B-4	B	B	C	C
B-5	B	B	B	B
B-6	B	B	B	B
B-7	B	C	C	C
B-8	B	B	B	B
B-9	B	B	B	B
B-10	B	B	B	B
B-11	B	B	B	C
B-12	B	B	B	C
B-13	B	B	B	C
B-14	C	C	C	C
BR-1	B	B	B	B
BR-2	B	B	B	B

We recommend that a professional engineer should design temporary support for trenches deeper than 20 feet, and that the OSHA tables are not used below this depth.

In general, it is HVJ's opinion that the pressure distribution (for braced walls) should be used for design of sheeting or trench boxes. To reduce the potential for ground movement adjacent to the top of the excavation, the bracing should be preloaded in stages as the excavation is deepened. The detailed earth pressure diagrams are presented on Plate 6.

The planned construction will be performed along alignments near existing utility installations (either crossing or paralleling the new alignments). The contractors should be aware of potential excavation stability problems while working in the vicinity of old trenches and the excavation system should be designed to accommodate this weak material (trench backfill).

The vertical walls of excavations should be located a safe distance from existing utilities in order to prevent movement in the soil mass behind the excavation that may adversely affect the utilities. We recommend that the horizontal distance of existing utilities should be greater than their vertical distance from the bottom of excavation.

7.3 Select Fill and General Earthwork Recommendations

The select fill required to rise the grade or backfill should consist of sandy clay with a liquid limit less than 40 and a plasticity index between 8 and 20. Fill material that is used should be placed in loose lifts not exceeding eight inches and should be compacted to 95 percent of standard Proctor maximum dry density as determined by ASTM D698.

7.4 Spoil Disposal

Spoil from construction will be generated from trench excavations. Soils that will be excavated from this project area will consist primarily of cohesive soils. Economically, possible uses of the cohesive spoil material may be limited to land reclamation, site grading, and final cover in sanitary landfill operations. These soils may not be suitable for use in engineered fill.

7.5 Groundwater Control

Based on our field investigation, limited groundwater seepage is expected during excavation at the invert depths of the utilities. Assessment of the need for groundwater control and installation of appropriate dewatering equipment is the contractor's responsibility at the time of construction. The following comments are intended to represent common solutions to groundwater control problems encountered in similar soil conditions in the Houston area, and may not be construed as dewatering system design recommendations. A conventional pump and sump arrangement may be adequate if water bearing cohesive soils are encountered during trench excavations. Well points or eductors may be utilized to lower the groundwater level to at least three feet below the excavation level where water bearing cohesionless soils are encountered. The 24 hour piezometer readings showed that substantial head exists in water bearing cohesive soils in some sections of the alignment (near borings B-4 and B-7) and in water bearing sands near boring B-14 and a significant raise in water levels can be expected during excavation since the water was encountered above the invert depth of the utilities. Based on the 24-hour water level readings, we expect groundwater at a depths ranging from 7 to 12 feet below existing ground throughout the project alignment. Well points are generally not effective below about 15 feet beneath the top of the well point, and deeper dewatering requires deep wells with submersible pumps and eductors. Based on these observations we expect dewatering techniques to be necessary in the section near boring B-14 of the project alignment. It should be noted that the need for dewatering may not be limited to the above mentioned section of the alignment. Control of groundwater should be accomplished in a manner that will preserve the strength of the foundation soils, will not cause instability of the excavation, and will not result in damage to existing structures. Where necessary, the water will be lowered in advance of excavation by pump and sump arrangement, wells, well points, or similar methods. Open pumping should not be permitted if it results in boils, loss of fines, softening of the subgrade, or excavation instability. Discharge should be arranged to facilitate sampling by the owner's representative or engineer.

8 BRIDGE FOUNDATION RECOMMENDATIONS

8.1 Analysis Criteria

The drilled shaft and driven pile capacities were calculated using the procedures described in the Texas Department of Transportation (TxDOT) Geotechnical Manual dated December, 2012. The method described was adapted to Houston District practice as documented in the Sep. 12, 1988 memo to District 12 Designers and Laboratory Geotechnical Engineers titled Guidelines for Foundation Design. Based on the information provided to us by AECOM, we understand that 24-inch diameter drilled shafts are considered for this project.

The following summarizes the Houston District adaptations to the procedures described in the Geotechnical Manual based on the memo and comments from Houston District Laboratory staff.

- For drilled shafts 24 inches in diameter or smaller end bearing is neglected.
- Skin friction calculated for a drilled shaft is reduced by a soil reduction factor of 0.7 this reduces the maximum allowable unit skin friction to 0.875 tsf.
- For fill material wherever encountered, skin friction capacity should be disregarded.
- For drilled shaft foundations the skin friction in the upper ten feet should be disregarded due to moisture fluctuations and non-reliable friction transfer. However, skin friction is neglected throughout the depth of Hoods Bayou plus scour depth. Based on the information provided by AECOM, depth of Hoods Bayou is 19 feet and scour depth is 12.1 feet. We recommend the skin friction in the upper 31.1 feet should be disregarded.

The Wincore computer program that incorporates TxDOT standard procedures was used to compute the allowable unit and accumulative skin friction for straight-sided drilled shafts and driven piles for the project structures. A soil reduction factor of 0.7 was used to obtain the skin friction curves for the drilled shafts.

8.2 Drilled Shaft and Driven Pile Axial Capacity

Allowable skin friction curves for drilled shafts and driven piles were calculated using the Wincore program and are presented in Appendix H and Appendix I, respectively. Wincore was developed and is distributed by TxDOT. Soil Strength Analysis table printouts from the Wincore program are also presented in those appendices. The curves were developed for each boring location. The allowable values shown include a factor of safety of 2 according to the TxDOT Geotechnical Manual.

For drilled shaft and driven pile foundations the allowable skin friction capacity for the upper 31.1 feet should be disregarded.

For drilled shafts 24 inches in diameter or smaller end bearing is neglected. Hence, the total allowable compressive capacity is equal to the total allowable skin friction capacity adjusted to remove the appropriate disregard depth. Allowable compressive capacity due to skin friction may be calculated from the curves by reading the accumulative skin friction value corresponding to the tip penetration (adjusted to remove the disregard depth of 31.1 feet) of the shaft/pile and multiplying the value by the shaft/pile perimeter. The maximum allowable drilled shaft service load

should be determined in accordance with Chapter 5; Section 3 of the TxDOT Geotechnical Manual dated December, 2012.

For driven piles, the total allowable compressive capacity is equal to the total allowable skin friction capacity adjusted to remove the disregard depth mentioned above. End bearing is neglected for driven piles. For abutments and trestle bent foundations the maximum allowable loads for 16, 18, and 20-inch square precast concrete piles are 75, 90, and 110 tons, respectively. On the other hand, for footings the maximum allowable loads for 16, 18, and 20-inch square precast concrete piles are 125, 175, and 225 tons, respectively. It should be noted that 14-inch square precast concrete piles should not be used due to breakage problems, and 24-inch square precast concrete piles should not be used due to limited availability.

8.3 Lateral Capacity

Foundation elements often have to withstand significant lateral loads in addition to axial loads. Wind forces on bridges are forms of lateral loading. Lateral loads on a drilled shaft or driven piles will be countered by the mobilization of resistance in the surrounding soils as the shaft deflects. The lateral load capacity of the shaft or pile, therefore, will depend on its relative stiffness, and the strength of the surrounding soils.

A rational analysis of a problem involving lateral loading on a pile or shaft must consider the interaction of the soil and the structure. Equilibrium of forces and compatibility of displacements throughout the total system are the two fundamental conditions that are to be satisfied in the analysis.

For vertical piles or shafts subjected to small and transient wind or traction loads, it may be assumed that they can sustain horizontal loads of up to 10 kips per foot of pile/shaft diameter or width, and a transient load of 20 kips per foot of diameter or width. These values are allowable capacities, but do not restrict lateral deflection to a given value. Deflection associated with these loads should be within acceptable limits for bridge structures.

If higher lateral loads are anticipated, battered piles should be considered. If the higher lateral loads must be resisted with vertical piles/shafts, a more detailed study should be done to provide lateral load capacity curves.

Lateral load analysis was beyond the scope of this study and should be performed using computer programs such as LPILE, etc. The input parameters for lateral load analysis are presented in Appendix J.

8.4 Group Effects

Groups of shafts/piles should have a center-to-center spacing of at least 2.5D when designing foundations using one row group of shafts/piles and 3D for foundations using two or more rows of shafts/piles where D is the diameter of the shaft/pile. For greater spacing, the total capacity will be equal to the sum of the capacities of the individual shafts/piles in the group. The group capacity may be less than the sum of individual capacities at closer spacing. If spacing smaller is planned, HVJ Associates, Inc. should be contacted to assess group capacity.

For laterally loaded shaft/pile groups, lateral load capacity primarily is developed by the outer row of shafts/piles on the side opposite the direction of lateral load, which we refer to as the "front" row. The lateral load contribution of shafts/piles behind the front row provides substantially less

resistance. In order to determine a conservative capacity of a shaft/pile group determine the lateral capacity of the front row shafts using a program such as LPILE or another appropriate method. For shafts/piles spaced at least 5 diameters apart the groups lateral load capacity is equal to the sum of the lateral capacity of the front row shafts/piles. For shafts/piles spaced at 3 diameters the lateral group efficiency is 90% of the full capacity based on the front row. For shafts/piles spaced at 2 diameters the lateral group efficiency is 80% of the full capacity of based on the front row capacity. A comprehensive analysis of group lateral load capacity that includes the contribution shafts/piles behind the front row was not in our scope.

8.5 Settlement

A detailed settlement analysis was not in our scope. However, drilled shaft settlement should be limited to be less than half (1/2) inch. Differential settlement will result from variances in subsurface condition, loading conditions and construction procedures, such as cleanliness of the bearing area.

8.6 Drilled Shaft Construction Recommendations

Drilled shaft construction and installation should follow TxDOT Standard Specification Item 416, TxDOT Construction Bulletin C-9, and ACI 336.1-01. Slurry displacement methods for drilled shaft construction are allowed under TxDOT Standard Specifications. Presented below are a few specific recommendations.

1. Drilled shaft excavations should be inspected for verticality and side sloughing. Verticality is specified at one inch in ten feet of the shaft length, and should be checked to the full depth of dry augering prior to introducing drilling mud.

2. Before placing concrete, the shaft bottom should be cleaned out with a drilling bucket in order to remove any sediments that may not be displaced by the concrete.

   The shaft bottoms should be cleaned with a "clean-out" bucket until rotation on the bottom without crowd (i.e. penetration under force) produces little spoil. Probing after clean out is essential to verify the condition of the base of the shaft.

3. Concrete placement should be accomplished as directed in TxDOT Standard Specification Item 416.3.6. The tremie pipe diameter should be at least eight times as large as the largest concrete aggregate size.

4. A computation of the final concrete volume for each shaft should be made. Shafts taking an unreasonably high or low volume of concrete should be cored to check their integrity.

5. If casing is used it should be extracted slowly and smoothly with a vibratory hammer. The casing should always remain at least one foot below the level of the concrete during placement. Our analyses assume no casing will be left in place. We should be informed if casing will be left in place so we may provide revised shaft capacity calculations.

6. Shaft excavations should not be made within three shaft diameters (edge to edge) of shafts that have been concreted within the last 24 hours.

8.7 Driven Pile Construction Recommendations

Methods and effects of pile installation are important considerations in the choice and design of pile foundation systems. Piles normally experience their largest stresses during installation. Pile and soil properties, embedment length and driving equipment are a few of the variables that must be considered. Piling should be installed in accordance with TxDOT Standard Specification Items 404 and 409, TxDOT Construction Bulletin C-8, and ACI 543R-12.

We recommend that wave equation analyses be performed as a basis for selecting the installation equipment and procedures based on their ability to ensure installation to the required penetration without damage to the piles. In addition, the wave equation analyses should be used to determine an acceptable blow count at final penetration to be used to field verify the design pile capacity. The following guidelines should be followed when installing precast concrete piles.

1. Adequate cushioning material should be provided between the pile driver and the pile head. A six to twelve-inch thick cushion of softwood is usually adequate for piles that are over 50 feet long. Cushioning material condition should be carefully observed and the cushion must be changed if excessive compression occurs or at least every three piles.

2. Based on our experience, piles can usually be safely driven to about 8 blows per inch. Consistent blow counts above 100 blows per foot are not advisable. Based on the blow counts encountered at borings BR-1 and BR-2, difficult driving conditions are expected around a depth of 60 feet below the existing grade.

3. Driving aids such as pilot holes may be needed to advance piles. Pilot holes can also be used to assist in pile alignment. Pilot holes, if used, should be developed using wet rotary or auger drilling methods. Jetting is not recommended for construction of pilot holes. Pilot holes constructed in accordance with TxDOT Standard Specification Section 404.3 can be large enough to cause a reduction in the skin friction capacity of square piling. The specification requirement allows a pilot hole depth of up to 5 feet, deeper pilot holes are allowed with the approval of the Engineer. Since the first 5 feet is within the disregard depth discussed in Sections 8.2 for driven piles there should be no impact on the allowable pile capacity. However, pilot holes constructed in accordance with Section 404.3 that extend deeper than five feet could reduce the allowable pile capacity depending on the diameter of the hole.

   We recommend that we be contacted to determine the potential impact on pile capacity if pilot holes for square piles that exceed two-thirds of the pile width extending deeper than 5 feet are used during construction.

4. The hammer, cushion and pile should be designed such that installation to design specifications can be realized with no damage to the pile.

5. The top of the pile should be perpendicular to the longitudinal axis in order to minimize damage to the pile edges during driving.

6. At the beginning of driving, when driving through relatively soft soils, or when driving through a pilot hole, driving stresses should be reduced by shortening the

hammer stroke so that the pile will be less likely to develop damage due to reflected tensile stresses.

7. The pile driving cap should fit loosely around the top of the pile so that torsional stresses do not develop in the pile. The cap should, however, be able to control the alignment of the pile.

8. Prior to driving, the pile should be properly aligned and held with fixed leads. The pile should not be realigned once driving has begun.

9. Clays and some silty soils tend to undergo a reduction in strength during pile driving and regain strength after pile installation. This phenomenon is usually referred to as freeze or set-up. The number and duration of delays in the driving program should be minimized so as to control the effect of set-up and pile heaving. Pilot holes will also minimize this effect.

10. Piles should be handled so as to avoid tensile cracks and impact damage.

9 BOX CULVERT DESIGN RECOMMENDATIONS

9.1 General

The project includes extension of the existing culvert at Old Hoods Bayou. Based on the drawings provided to us by AECOM, the invert depth of the box culverts is about 8 to 10 feet below the existing grade. We have utilized the soils information from boring B-1 to develop recommendations for the Box Culverts. Design guidelines and recommendations for the Box Culvert placed by open-cut techniques are discussed in the following sections.

Geotechnical Parameters for Box Culverts. Geotechnical parameters for design are presented in the following table. Shear strength parameters given in the table are based on field and laboratory data obtained at boring location B-1 only within the given invert depth zone. It must be noted also that because of the nature of soil deposits, parameters at locations away from the borings may vary substantially from values reported in the table.

Table 9-1 Box Culvert Allowable Bearing Capacity

Boring No.	Location	Approximate Invert Depth (ft)	Soil Description	Total Unit Weight (pcf)	Undrained Shear Strength (psf)	Allowable Bearing Capacity (psf)
B-1	STA 31+50	8-10	Soft Sandy Lean Clay	138	2400	4,000

The values shown in the above table represent our interpretation of the soil properties based on the available laboratory and field test data. Use of the soil properties shown above may or may not be appropriate for a particular analysis since choice of design parameters often depends on whether total or effective stress analysis is used, rate of loading, duration of loading, geometry of loaded area, and other factors. The total unit weight values shown above represent our interpretation of soil unit weight at natural moisture content.

Design Lateral Pressure. The soil pressure exerted on the culvert wall is mainly a function of the type of backfill and its method of placement. Over-compaction of backfill behind walls and utilization of highly plastic expansive clay backfill are practices that generally produce the highest wall pressures. In these cases, horizontal earth pressures exceeding the vertical earth pressure can be expected. Design at-rest lateral pressures for culvert walls may be calculated for each backfill type using the equivalent fluid densities for drained level backfill as stated in the following Table.

Table 9-2 Lateral Earth Pressure of Culvert Backfill

Fill Type	Equivalent Fluid Density (pcf)
Select Cohesive Soil (PI<20)	70
Bank Sand	55
On Site Cohesive Soil (PI >20)	90

Over-compaction of the backfill should be avoided to prevent the increase of lateral earth pressures on the box culverts. The recommended design pressures do not include a groundwater pressure component.

Vertical Soil Loads. Loading on the top of the Culvert may be calculated using a total soil unit weight of 130 pounds per cubic foot (pcf). For buoyancy calculations, the unit weight of soil should be taken as 65 pcf, which assumes a water table at the ground surface.

9.2 Concrete Box Culvert Design

The modulus of subgrade reaction of subsurface soils at the given invert depth of the proposed box culverts are presented in the table below.

Table 9-3 Box Culvert Design

Boring No.	Location	Invert Depth (feet)	Modulus of Subgrade Reaction (k)
B-1	STA 31+00	8-10	100 pci

Bedding and Backfill. Bedding and backfill for box culvert should be performed in accordance with TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 400.

10 DETENTION BASIN AND HOODS BAYOU SLOPE STABILITY ANALYSIS

10.1 General

The project involves construction of a detention basin (approximately 2.5 acres) on south of Payton Road (Key Map No. 373R) in Houston, Texas. Based on the cross section provided to us by AECOM, we understand that the basin slope will be 4H:1V. We performed the stability analysis for 4H:1V slope with soil profile having maximum plasticity indices. The depth of the basin will not

exceed 13.5 feet below the crest level. The proposed detention basin sections are presented in Appendix L of the report. We have performed the slope stability analyses for all the loading conditions (End of Construction, Rapid Drawdown, Long-Term). The details are provided in the subsequent sections of this report.

Based on the cross section provided to us by AECOM, we understand that the proposed Hoods Bayou slope at bridge abutment location will be 2H:1V at west bank and 3H:1V at east bank (Appendix R). Hence, we performed the stability analysis for 2H:1V slope with soil profile having maximum plasticity indices. The proposed Hoods Bayou sections are presented in Appendix R of the report. We have performed the slope stability analyses for all the loading conditions (End of Construction, Rapid Drawdown, Long-Term). The details are provided in the subsequent sections of this report.

10.2 Slope Stability Analysis

The following are the minimum HCFCD required factors of safety for the different loading conditions that are expected during the lifetime of a slope:

Table 10-1 HCFCD Required Factors of Safety

Loading Conditions	Minimum Factor of Safety Required
End of Construction (EOC)	1.3
Rapid Drawdown (RDD)	1.25
Long-Term (LT)	1.5

The factors of safety represent the calculated ratio of resisting forces and moments to the calculated driving forces and moments for the various potential failure surfaces analyzed. These forces and moments are based on the estimated unit weights and shear strengths of the various soils in the slope profile. Accordingly, a factor of safety of 1.0 indicates impending failure. The greater than 1.0 the factor is, the lower the risk of slope failure. As a practical matter, and in consideration of the variables and uncertainties involved, the risk cannot be reduced to zero. The goal is to reduce the risk of slope failure to a reasonable and acceptable level, with due consideration of the consequences of failure.

10.3 Method of Analysis

Stability analyses were conducted using SLOPE/W slope stability program that calculates the factor of safety against slope failure using a two-dimensional limiting equilibrium method. Morgenstern-Price method was employed to evaluate the factor of safety for the slope.

10.4 Soil Parameters and Water Level

The soil parameters used in each case are discussed below and were estimated based on the field and laboratory data developed for this study, and also our experience with similar soils. Unconsolidated Undrained tests (UU) were conducted to estimate the shear strength parameters for the short term analysis. CU Triaxial compression tests with pore pressure measurements have been conducted to estimate the shear strength parameters for the long term and rapid draw down analysis. The consolidated undrained (CU) triaxial compression test results are included in Appendix G in the final report.

End of Construction (EOC). The end of construction case models the initial undrained condition of the soil. For this analysis, Unconsolidated Undrained soil parameters were used as per the HCFCD guidelines. In this analysis, the piezometric level was taken at the toe level of the slope. A

surcharge of 250 psf was assumed from the edge of the slope. The undrained shear strength parameters were the lowest values of unconsolidated undrained (UU) test results for a particular soil layer in the boring.

Long Term (LT). The long-term design case represents steady state piezometric and stress conditions. When a slope is excavated, altered stress conditions create pore pressure changes within the slope and the undrained strength of the bank soils is mobilized. With time, the soil pore pressures adjust to the imposed stress and piezometric conditions, and the bank soils rely on their available strength for long-term stability. In this analysis, the piezometric level was taken about 2 feet above the toe level of the slope. A surcharge of 250 psf was assumed from the edge of the detention basin.

Rapid Drawdown (RDD). The rapid drawdown design case represents the rapid lowering of water level and associated stress conditions. When the water level is lowered in a short duration of time, it destabilizes the slope due to the development of excess pore pressures in the embankment consisting of low permeability materials (e.g., clay) and removal of stabilizing force on the upstream face of the slope due to water. In this analysis, we will assume a drawdown of the water level from 100-year flood level to the toe level. The program SLOPE/W utilizes the Duncan et al.'s (1992) staged rapid drawdown method to evaluate slope stability after rapid drawdown. This is a 3-stage process:

The first stage involves the stability analysis of the embankment before drawdown when the water level is high and the pore water pressure in the soils is at steady state condition. Both the effective normal stress and the shear stress along the slip surface are used to determine the undrained shear strength of the soils that do not drain freely.

The second stage involves the stability analysis of the embankment after drawdown when the water level is low and the pore water pressure in the soils is in steady state condition. The effective normal stress obtained from stage two, together with the effective strength parameters are used to compute the drained strength along the slip surface. Both the drained and undrained strength at the slice base along the slip surface are compared and the smaller strength is chosen as the computed shear strength to be used.

The third stage involves stability analysis using the computed shear strength and final drawdown water level. The computed factor of safety from the first and second stages are ignored, and only the factor of safety computed from the third stage analysis is used to represent the stability after rapid drawdown.

Shear Strength

The shear strengths of the soils were determined from a combination of CU and classification tests results, visual interpretation, experience with HCFCD and engineering judgment.

Table 10-2 Consolidated Undrained (CU) Triaxial Test Results

Boring No.	Sample Description	Sample Depth, feet	Unit Weight (pcf)	% Passing #200 Sieve	Atterberg's Limits		Effective Stress Parameters		Total Stress Parameters	
					LL (%)	PI (%)	c' (psf)	ϕ' (deg)	c (psf)	ϕ (deg)
DP-1	Lean Clay with Sand (CL)	10-12	130	84.5	33	10	106	28.3	180	24.9

Boring No.	Sample Description	Sample Depth, feet	Unit Weight (pcf)	% Passing #200 Sieve	Atterberg's Limits		Effective Stress Parameters		Total Stress Parameters	
					LL (%)	PI (%)	c' (psf)	ϕ' (deg)	c (psf)	ϕ (deg)
DP-3	Lean Clay (CL)	18-20	130	90.5	44	28	650	22.2	1370	15.7

Note: The effective cohesion of 650 psf was observed to be high and will be limited to 350 psf for engineering analysis based on our experience with similar soils and HCFCD.

Peak Soil Parameters for Detention Pond Slope Stability analysis

The peak soil shear strength parameters for rapid drawdown and long term loading conditions were developed from a combination of CU and classification tests results, visual interpretation, experience with HCFCD, and engineering judgment. The Boring DP-2 was chosen as representative soil profile since it shows maximum plasticity indices. Following tables presents the parameters used for short term, long term and rapid drawdown cases. The Lean Clay (CL) layer in boring DP-2 (10-25 feet below the existing grade) was found comparable to the thin Fat Clay (CH) layer observed in the same boring (8-10 feet below the existing grade) in terms of classification tests. Owing to their comparable properties, HVJ believes these soils will show similar engineering behavior. Therefore, the values of shear strength obtained from the CU test on Lean Clay sample was also utilized for the fat clay found on site.

Table 10-3 Peak Soil Parameters used for Detention Pond Slope Stability Analysis

Stratum	Elevation, Feet	Description	Max. Plasticity Index (%)	Unit Weight	EOC		LT/RDD	
				γ_t (pcf)	c_u (psf)	ϕ_u (deg)	c' (psf)	ϕ' (deg)
1	0-8	Lean Clay-1	21	130	1700	0	350	22.2
2	8-10	Fat Clay	31	135	3600	0	350	22.2
3	10-25	Lean Clay-2	28	130	1920	0	350	22.2

Note: Effective stress parameters were used for both long term and rapid draw down analysis based on our experience with HCFCD.

Weathered Soil Parameters for Detention Pond Slope Stability Analysis

The shear strength for long term and rapid drawdown will be reduced as per the HCFCD's guidelines for the top 8 feet from the surface of the slope for the cohesive soils with Plasticity Index greater than 20.

Table 10-4 Weathered Soil Parameters used for Detention Pond Slope Stability Analysis

Stratum	Depth, feet	Description	Max. Plasticity Index (%)	η^{**}	LT/RDD	
					c' (psf)	ϕ' (deg)
1	0-8	Lean Clay-1	21	0.96	100	22.2
2	8-10	Fat Clay	31	0.59	26	22.2
3	10-25	Lean Clay-2	28	0.68	50	22.2

Note: The weathered cohesion for Lean Clay-1 and Lean Clay-2 layers were calculated to be 319 psf and 97 psf, and were limited to 100 psf and 50 psf, respectively for analysis based on our experience with HCFCD.

Peak Soil Parameters for Hoods Bayou Slope Stability Analysis

The peak soil shear strength parameters for rapid drawdown and long term loading conditions were developed from a combination of CU and classification tests results, visual interpretation, experience with HCFCD, and engineering judgment. The soil profile was developed from borings BR-1 and BR-2. Following tables presents the parameters used for short term, long term and rapid drawdown cases.

Table 10-5 Peak Soil Parameters used for Hoods Bayou Slope Stability Analysis

Stratum	Depth, Feet	Description	Max. Plasticity Index (%)	Unit Weight	EOC		LT/RDD	
				γ_t (pcf)	c_u (psf)	ϕ_u (deg)	c' (psf)	ϕ' (deg)
1	0-10	Lean Clay-1	13	125	1400	0	350	22.2
2	10-27	Lean Clay-2	25	125	1400	0	350	22.2

Note: Effective stress parameters were used for both long term and rapid draw down analysis based on our experience with HCFCD.

Weathered Soil Parameters for Hoods Bayou Slope Stability Analysis

The shear strength for long term and rapid drawdown will be reduced as per the HCFCD's guidelines for the top 8 feet from the surface of the slope for the cohesive soils with Plasticity Index greater than 20.

Table 10-6 Weathered Soil Parameters used for Hoods Bayou Slope Stability Analysis

Stratum	Depth, feet	Description	Max. Plasticity Index (%)	η^{**}	LT/RDD	
					c' (psf)	ϕ' (deg)
1	0-10	Lean Clay-2	25	0.8	50	22.2

Note: The weathered cohesion for Lean Clay-2 was calculated to be 192 psf and limited to 50 psf for analysis based on our experience with similar soils.

Where:

EOC: End of Construction
RDD: Rapid Drawdown
LT: Long Term
γ_t: Moist Unit Weight of Soil
ϕ': Effective Friction Angle
c': Effective Cohesion

10.5 Computed Factors of Safety of the Analyzed Slopes

Based on the soil parameters and water levels discussed in Section 10.4, slope stability analyses were performed and the results of our analysis are presented in the table below. The SLOPE/W outputs for pond and bayou are attached in Appendix M and Appendix S, respectively.

Table 10-7 Results of Slope Stability Analysis

Detention Pond Slope	Global Stability		
	End of Construction	Long Term	Rapid Drawdown
Detention Pond (4H:1V)	7.1	2.0	1.8
Hoods Bayou (2H:1V)	3.7	1.5	1.3

10.6 Discussion of the Slope Stability Results

Based on our analysis, the proposed cross sections provided by AECOM for the pond and bayou are safe.

10.7 Dispersive Soils

Dispersive soils are soils that disintegrate in the presence of relatively pure water as a result of their chemical composition. Such soils are highly susceptible to erosion and piping and are a major cause of slope distress in areas where they occur. Crumb and Pinhole tests were conducted to identify the presence of dispersive soils at the site. Crumb and Pinhole test results show that the soils at the site are generally non dispersive.

10.8 Erosion Protection and Slope Construction

Erosion Protection. Erosion control measures will be needed wherever sand, dispersive soils or fill material is exposed. Based on the borings drilled for this study, we do not expect these conditions. However, the use of erosion protection is recommended. Turf establishment following Harris County Flood Control District (HCFCD) Standard Specifications, 2005 Section 02921 and use of staggered sod strips would be advisable. Several alternative erosion protection measures are discussed below.

Geocomposites. Specialty geocomposites have been developed by many manufacturers for erosion control applications. The goal of such systems is to prevent sheet, gully or rill erosion either indefinitely or until vegetation can establish itself. These materials are installed by pinning or stapling them to the soil on a prepared subgrade and should be in accordance with HCFCD Standard Specifications, 2005 Section 02379. Typical failure mechanisms are water flow between the fabric and the soil or undermining at roll edges. Manufacturer's installation recommendations should be followed.

Temporary erosion control materials are designed to remain in place until vegetation is established. They are partially or completely biodegradable after a period of time.

We recommend a permanent erosion control system, in which the geocomposite material is placed and becomes enmeshed with the vegetation root system. Such materials are placed as above, and then soil backfill is placed within and above the material. The fill is seeded or the soil subgrade is seeded prior to geocomposite and backfill placement. The fill soil partially protects the geocomposite material from ultraviolet degradation, and forms the medium for root growth.

Riprap. Stone or concrete riprap may also be used for the project that will satisfy the requirements of HCFCD Standard Specifications, dated December 2010. We recommend that a geotextile filter conforming to the requirements of HCFCD Standard Specification, 2010 Section 02379 should be installed as a filter beneath stone or concrete riprap to reduce erosion of soils from beneath the riprap. Stone or concrete riprap should also be used in areas where high flow velocities are anticipated such as near inlets, outlets and spillways.

Slope Construction

Detention basin slope should be constructed in accordance with HCFCD Specification Section 02224.

Compaction: HVJ recommends that the degraded crest and any portion of the slope that is reworked be compacted to 95% standard proctor density in accordance with ASTM D698 as specified in Harris County Flood Control District Standard specifications, Section 02315.

11 PAVEMENT DESIGN RECOMMENDATIONS

11.1 General

The pavement thickness design for Greens Road from Aldine-Westfield Rd. to JFK Blvd. in Houston, Texas was performed using the 2011 TxDOT Pavement Design Guide and DARWin computer program. The design inputs required include: Design and performance constraints, traffic, pavement layer characterization and subgrade strength.

Greens Road will be widened by extending the right of way towards the north on the portion of Greens Road that is east of Hoods Bayou, and by extending the right of way towards the south on the portion of Greens Road that is west of Hoods Bayou. HVJ understands that the pavement along the roadway will be reconstructed with Portland Cement Concrete (PCC).

Lime Stabilized Subgrade was considered for the subbase directly under concrete. As background for the consideration, the purpose of subgrade stabilization is to help alleviate the following potential problems: 1) When concrete pavement is placed directly on subgrade, there is a propensity of the subgrade fines to pump through the concrete joints, creating voids under the concrete and with loading result in corner cracks and faulting that can progress and cause premature failure in the concrete pavement; and 2) For expansive subgrade soils, there is a desire to minimize the shrink/swell movement which causes pavement distress.

The lime stabilization of the subgrade provides the following benefits: 1) a depth of non-swelling material, 2) a moisture barrier to minimize moisture fluctuations in the subgrade that can cause shrinkage/swelling; and 3) helps bind the fines and delay potential pumping, however is still considered an erodable material.

Based on over 80 years of combined pavement design experience all over the United States as specialized pavement engineers in HVJ's Pavement Unit, a non-erodible base is suggested to provide a more durable concrete pavement. The following benefits contribute to improved pavement performance with a stabilized, non-erodible base: added depth of non-swelling material, a moisture barrier to minimize moisture fluctuations in the subgrade that can cause shrink/swell conditions; and eliminate pumping at joints that results in loss of support and cracking. By retaining lime stabilized subgrade under a stabilized base, the pavement section would be further protected from swelling soils pavement distress. If an alternative pavement design with a non-erodible base (i.e. cement stabilized base or HMAC base) is desired, notify HVJ.

11.2 Traffic Data

Traffic assumptions are based on traffic analysis provided within the project limits by TxDOT dated September 15, 2014 for 30 year period for rigid pavement design. Traffic data in this report provided 2014 and 2044 Traffic Planning and Programming Division (TP&P) information for Greens Road from Aldine-Westfield Rd to JFK Blvd. TP&P data included average daily traffic (ADT) counts, directional distribution, as well as percent trucks. This traffic data is presented below and included in Appendix N.

2014 ADT – 13,900

2044 ADT – 21,700
Rigid Pavement 30-year period – 4,198,000 ESALs (based on 8" slab thickness)

AECOM requested HVJ to provide a 50-year pavement design. The TP&P data provides the initial ADT of 13,900 with 1.87% growth rate. The design 18 kip Equivalent Single Axle Loads (ESALs) in one direction was then calculated based on 5.3% trucks and an estimated average truck factor of 0.691 for rigid pavement resulting in a 50-year design ESALs of 8,033,541.

11.3 Design Criteria and Performance Constraints

The design and performance constraints include reliability level, performance period, initial serviceability index after construction, and terminal serviceability index, which are based on guidance in the 2011 TxDOT Pavement Design Guide.

Reliability Level and Overall Standard Deviation. - A reliability (R) of 95 percent was used for rigid pavement with more than 5 million design ESALs and a reliability of 90% was used for 5 million or less design ESALs. A mean value of the overall standard deviation (S_o) was selected to be 0.39 for Portland cement concrete pavement in which future traffic is considered.

Serviceability: The serviceability of a pavement is defined as its ability to serve the type of traffic that uses the facility. The condition of the pavement after the performance period is characterized by a Terminal Serviceability Index (Pt), which is a function of the pavement structure. A Terminal Serviceability Index of 2.5 is recommended. Since the time at which a given pavement structure reaches its terminal serviceability depends on traffic volume and the original or initial serviceability (Po), some consideration also must be given to the selection of Po. As obtained at the AASHTO Road Test, a Po value of 4.5 was selected. The design serviceability loss, the difference between the initial and terminal serviceability indices is 2.0.

Drainage: The treatment for the expected level of drainage for a rigid pavement is through the use of a drainage coefficient, C_d. Based on average annual precipitation of 50 inches in Houston, a C_d value of 0.95 was selected for design.

Load Transfer: The load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer load across discontinuities, such as joints. Based on the values developed by AASHTO, a mean value of the load transfer coefficient (J) of 2.9 was selected for the design of jointed tied PCC shoulders/ or curb and gutter and load transfer at transverse joints, as per AASHTO Guide.

Loss of Support: This factor, LS, was included in the design of rigid pavement to account for the potential loss of support arising from subbase erosion and/or differential vertical soil movement. An LS value of 2.0 was selected for Lime stabilized subgrade as per guidance in the AASHTO Guide.

11.4 Material Properties for Structural Design

Concrete Elastic Modulus and Modulus of Rupture: Based on the 2011 TxDOT Pavement Design Guide, a mean value of 620 psi for S'c is recommended to be used with the current statewide specification. A value of 5×10^6 psi is also recommended by the design guide for the modulus of elasticity of the concrete (E_c).

Subgrade Strength

Based on field investigations, the subsurface soil at the location of the borings generally consisted of fat and lean clays (CH and CL). Laboratory tests were run to determine the engineering properties of the soil. The subgrade modulus was estimated based on Texas Triaxial correlations to the plasticity index (PI).

Based on the highest PI encountered, the subgrade modulus selected for design was 2,500 psi to ensure pavement design adequacy for the weakest areas.

Effective Modulus of Subgrade Reaction: The composite K-value required for rigid pavement design was calculated to account for the underlying base or subgrade and the potential loss of support arising from subbase erosion. For Lime Stabilized Subgrade, the effective modulus of subgrade reaction (k) was calculated to be: 24 pci for 8" Lime Stabilized Subgrade.

11.5 Summary of Rigid Pavement Design Inputs

The estimated and/or assumed values for the parameters relative to these categories are summarized in the following table:

Table 11-1 Summary of Design Inputs

Parameter	Value
Subgrade Resilient Modulus, M_R	2,500 psi
Lime Stabilized Subgrade Thickness, D_{sb}	8 inches
Lime Stabilized Subgrade Elastic Modulus, Esb	20,000 psi
Loss of Support Factor, LS	
• Lime Stabilized Subgrade	2
Concrete Elastic Modulus, E_c	5 x 10^6 psi
Mean Concrete Modulus of Rupture, S'_c	620 psi
Load Transfer Coefficient, J	2.9
Drainage Coefficient, C_d	0.95
Design Serviceability Loss, D	2.0
Reliability, R (5 million or less ESALs)	90%
Reliability, R (greater than 5 million ESALs)	95%
Overall Standard Deviation, S_o	0.39
Design Traffic ESALs (30-year design life)	4,198,000
Design Traffic ESALs (50-year design life)	8,033,541

11.6 Rigid Pavement Recommendations

Based on the previous input factors including design and performance constraints, traffic, and subgrade soils, DARWin was used to run rigid pavement alternatives for a 30-year and 50-year design life for Greens Road.

Table 11-2 below summarizes the resulting Jointed Reinforced Concrete Pavement (JRCP) cross sections for Greens Road within the project limits. Pavement design outputs are presented in Appendix O.

Table 11-2 Summary of Proposed Pavement Thickness

Street	Cross Section (30-year design life)	Cross Section (50-year design life)

Greens Road	10" JRCP 8" Lime Stabilized Subgrade	11.5" JRCP 8" Lime Stabilized Subgrade

Jointed Reinforced Concrete Pavement and Lime Stabilized Subgrade shall be in accordance to TxDOT specifications Item 360 and Item 260 respectively.

11.7 Preparation of Subgrade

HVJ performed a lime series on a composite sample of borings B-4, B-6, and B-12 along Greens Road. Based on the lime series test results, 6% lime per dry unit weight appears to be an adequate estimate for stabilization of the onsite clays to perform satisfactory as pavement subgrade. The lime series test results are presented in Appendix P. The lime percentages are only estimations based on test results of the material at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations. Once the subgrade is exposed, the contractor should perform additional lime series testing to confirm the lime percentage for each soil variation encountered.

HVJ recommends the following procedures for subgrade preparation.

1. Clear the proposed project limits of existing pavement and subgrade to the grade required for the proposed pavement section.

2. In areas where soft, compressible or loose soils are encountered, additional excavation may be required. Excavation should extend a minimum of two feet beyond the edge of the proposed pavement, if appropriate.

3. Surfaces exposed after excavation should be proof-rolled in accordance with TxDOT Standard Specification Item 216. If rutting develops, tire pressures should be reduced. The purpose of the proof-rolling operation is to identify any underlying zones or pockets of soft soils and to remove such weak materials.

4. Before stabilizing the subgrade, scarify the upper eight inches of exposed material throughout the width of pavement as required to provide loose material to facilitate distribution of lime. Mix 6% lime by dry weight and compact to 95 percent of standard proctor maximum dry density (ASTM D698). HVJ's lime series test results should be verified at the time of construction for subgrade soils by conducting laboratory tests on the exposed subgrade material during construction.

12 MONITORING

12.1 Excavation Safety

As required under OSHA regulations, the contractor should provide a "competent person" to inspect trench excavations daily before the start of work, as needed during the shift, and after every rainstorm or other hazard increasing occurrence. When the competent person finds evidence of a hazardous condition, exposed workers should be removed from the hazardous area until the necessary precautions have been taken to ensure their safety. A competent person means one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to workers, and who has authorization to take prompt corrective measures to eliminate them.

12.2 Construction Materials Testing

HVJ recommends that backfill be monitored by an accredited testing laboratory to verify that construction is performed in conformance with project specifications. HVJ routinely provides materials testing verification and observation services and would be pleased to do so for this project.

13 DESIGN REVIEW

HVJ should be retained to review the final design plans and specifications for this project to determine whether the geotechnical recommendations have been properly interpreted, and to confirm that the assumptions made at the time this report was prepared are consistent with the project as finally design.

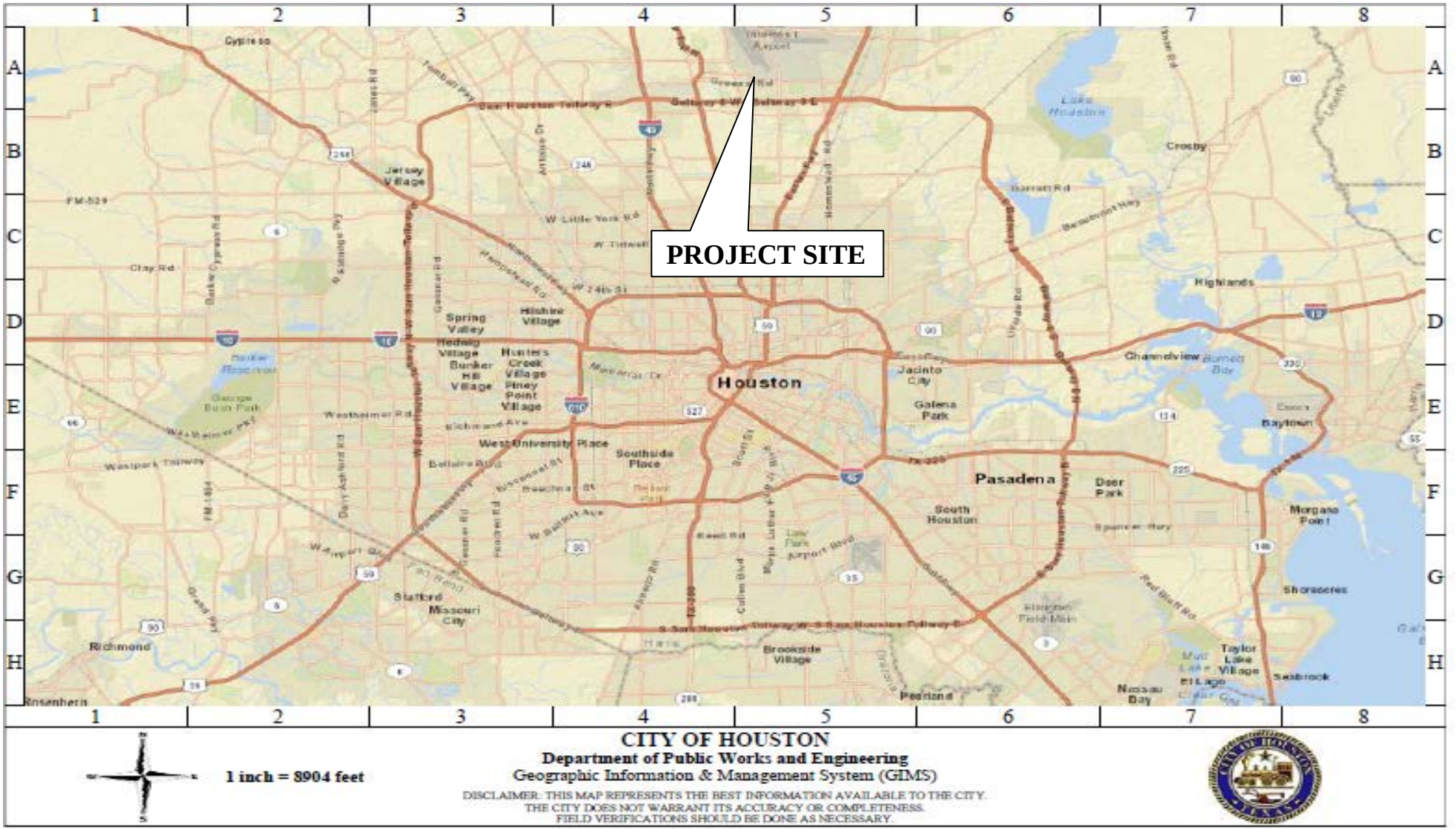
14 LIMITATIONS

This investigation was performed for the exclusive use of AECOM, Texas Department of Transportation and City of Houston to provide geotechnical and pavement recommendations for the improvement of Greens Road from Aldine Westfield to JFK in Houston, Texas. HVJ has endeavored to comply with generally accepted geotechnical engineering practice common in the local area. HVJ makes no warranty, express or implied. The analyses and recommendations contained in this report are based on data obtained from subsurface exploration, laboratory testing, the project information provided to us and our experience with similar soils and area conditions. The methods used indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations. Should any subsurface conditions other than those described in our boring logs be encountered, HVJ should be immediately notified so that further investigation and supplemental recommendations can be provided.

15 REFERENCES

1. American Water Works Association (2008). "AWWA Manual M9" Third Edition.
2. City Of Houston Department Of Public Works And Engineering (July 2012) "Infrastructure Design Manual"
3. American Association Of State Highway And Transportation Officials (1993) "AASHTO Guide for Design of Pavement Structures"
4. Bowles, J.E. (1988). Foundation Analysis and Design. Fourth Edition, McGraw-Hill Book Company, New York, pp. 141-142.
5. Davisson, M.T. (1970a). Lateral Load Capacity of Piles, Hwy. Res. Rec., 333, pp. 104-112.

PLATES



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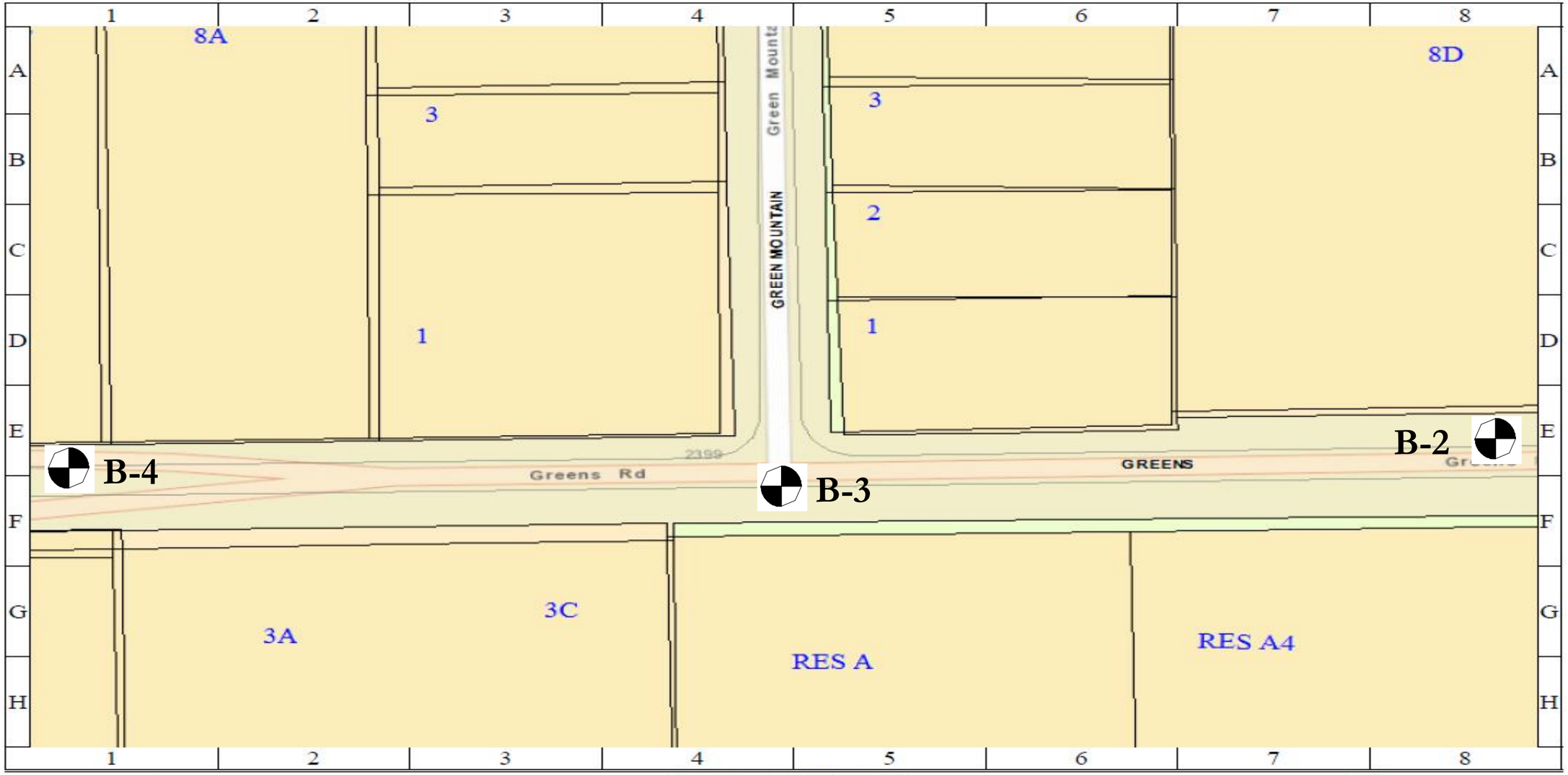
DATE: 08/18/2014	APPROVED BY: ND	PREPARED BY: SS

SITE VICINITY
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No. N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 1



N
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1 inch = 29 feet

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Department of Public Works and Engineering
Geographic Information & Management System (GIMS)

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LEGEND:

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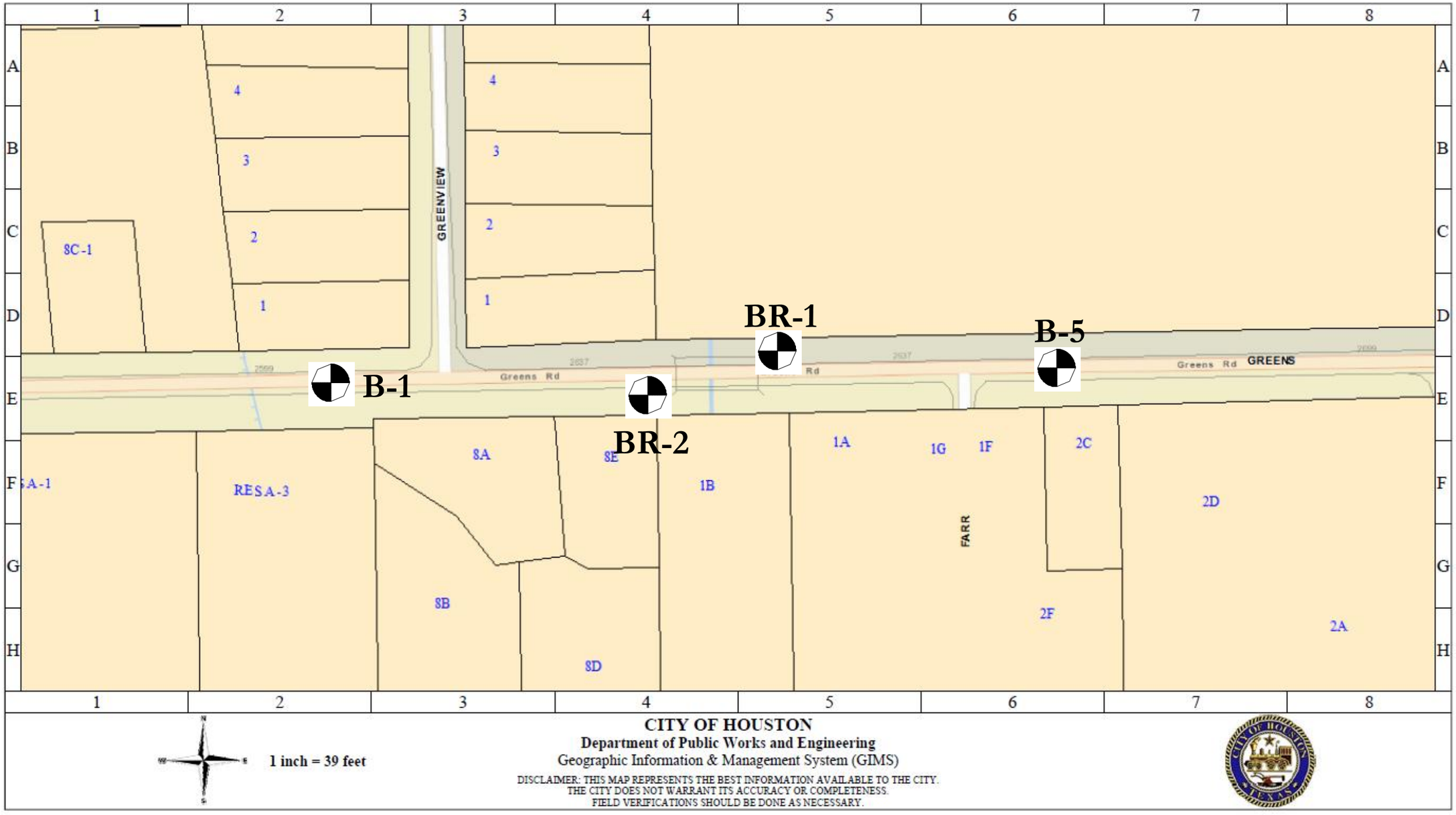
PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE 2A



LEGEND:

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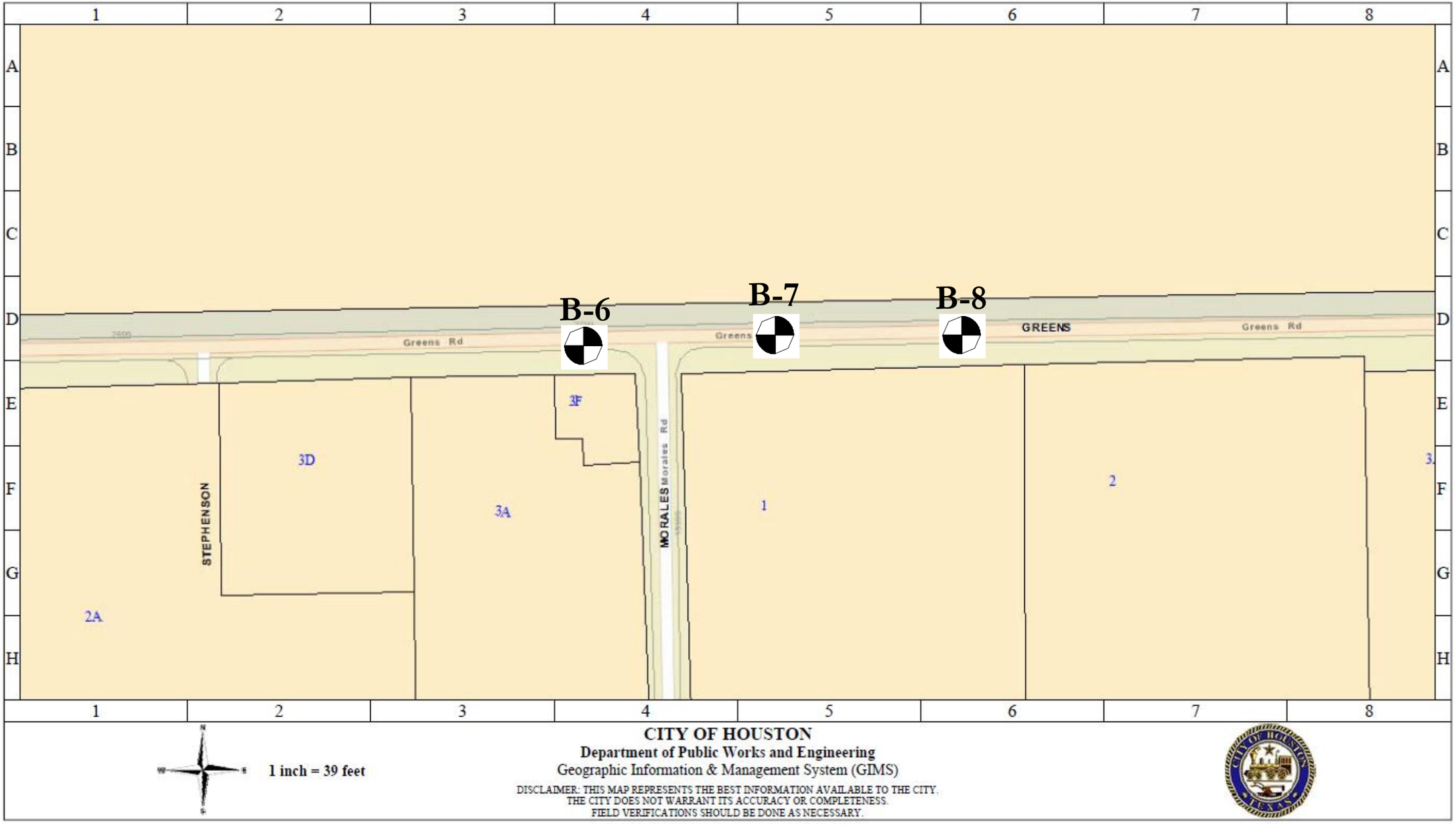
PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 2B



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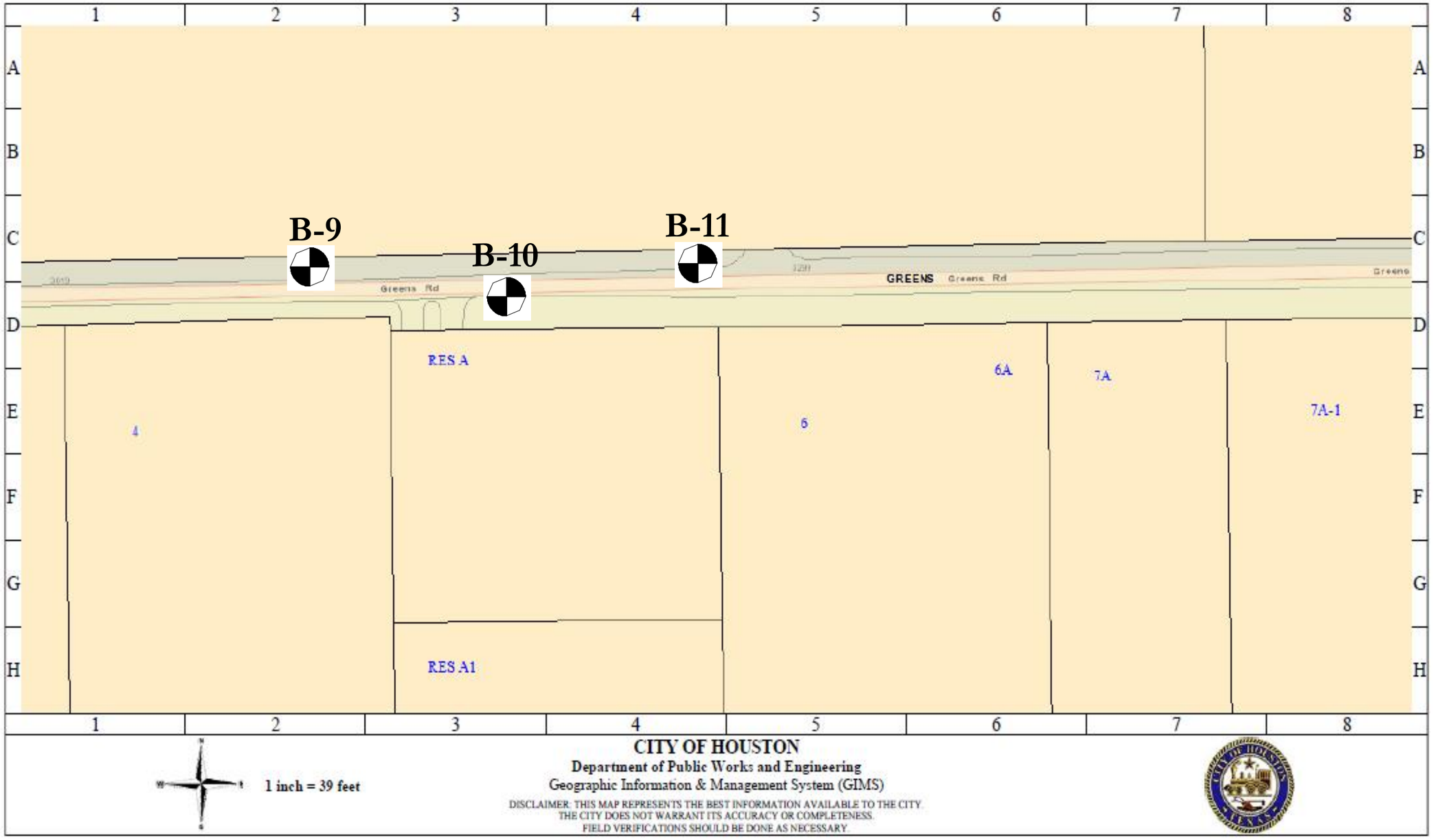
PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 2C



LEGEND:

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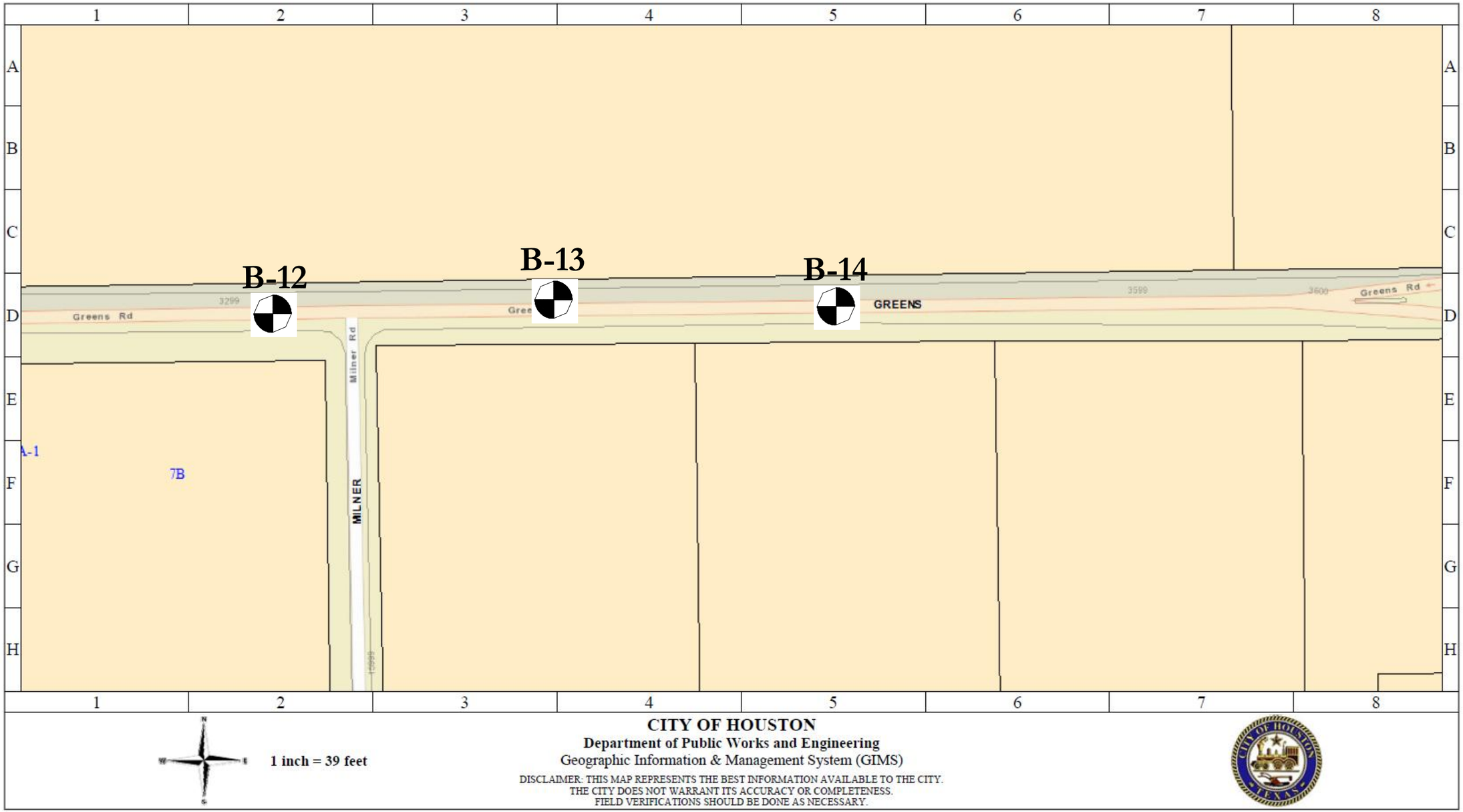
PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 2D



1 inch = 39 feet

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FIELD VERIFICATIONS SHOULD BE DONE AS NECESSARY.

LEGEND:

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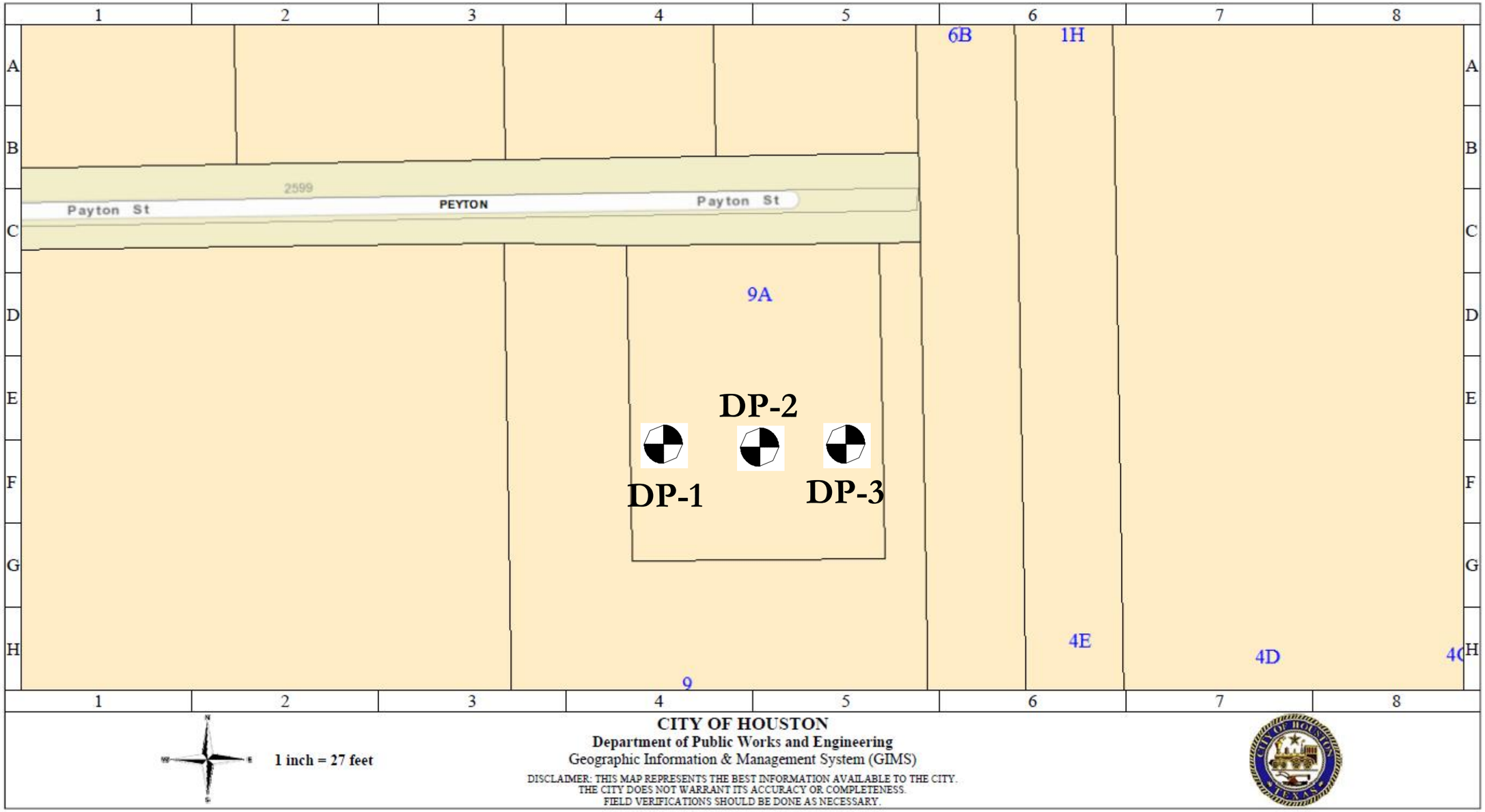
PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 2E



LEGEND:

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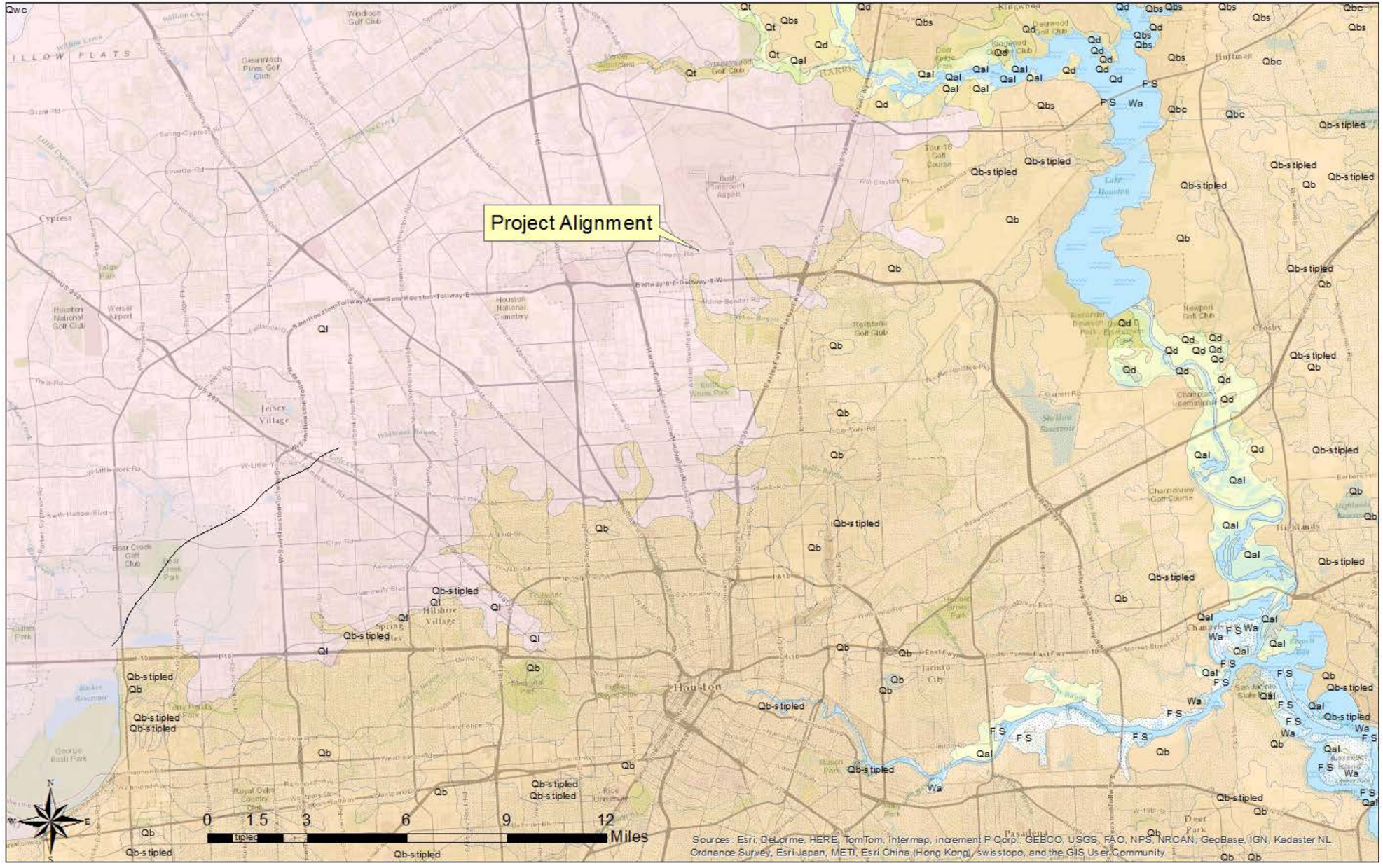
DATE: 09/12/2014	APPROVED BY: MM	PREPARED BY: KL

PLAN OF BORINGS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS NO.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE 2F



Ql

Lissie Formation - Upper part, clay, slit, sand, and very minor siliceous gravel of granule and small pebble size gravel more abundant northwestward, locally calcareous, concretions of calcium carbonate, iron oxide, and iron-manganese oxides common in zone of weathering; fluviatile; surface fairly flat and featureless except for numerous rounded shallow depressions and pimple mounds, bower part, clay, silt, sand,

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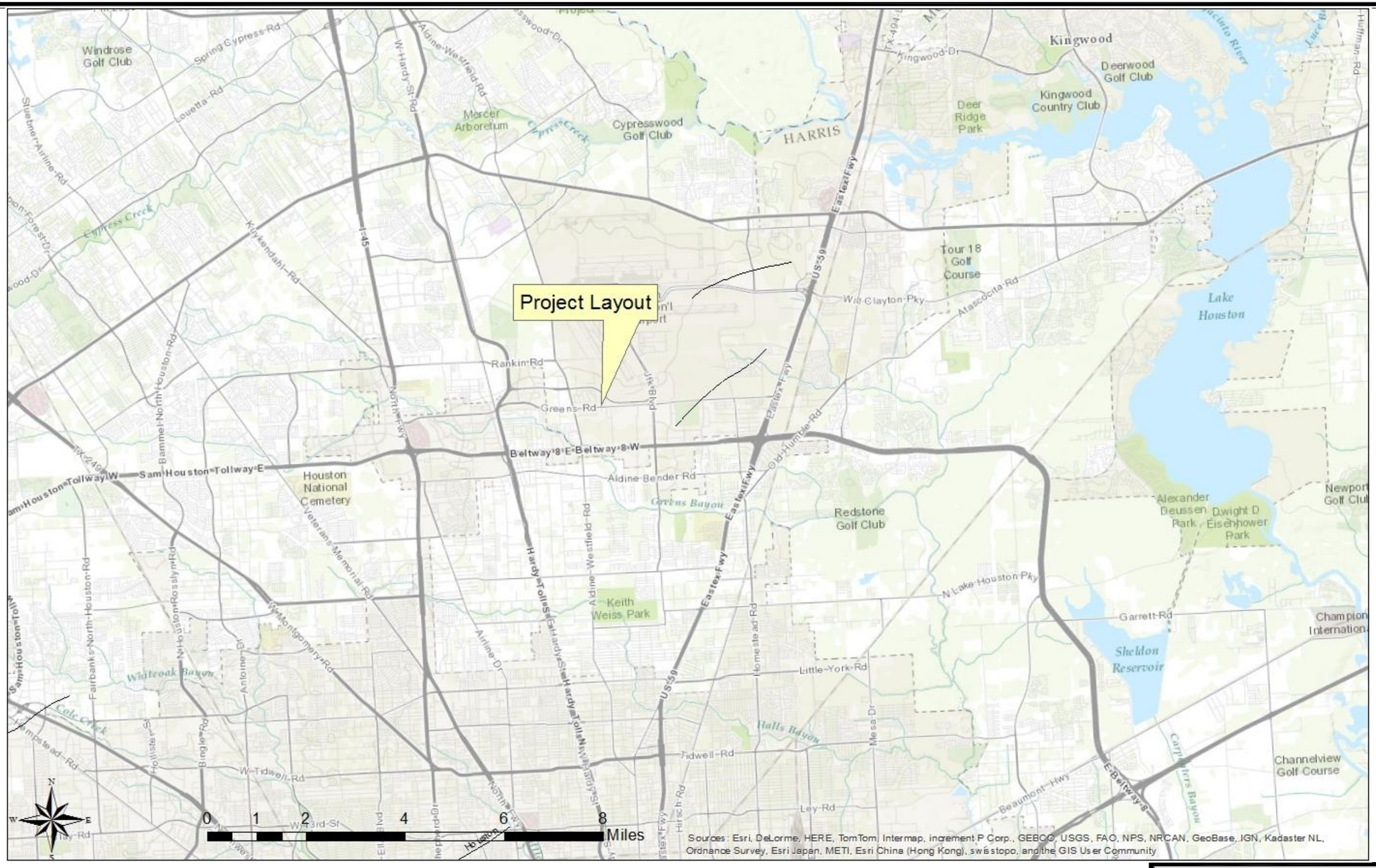
GEOLOGIC MAP
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No. N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE 3



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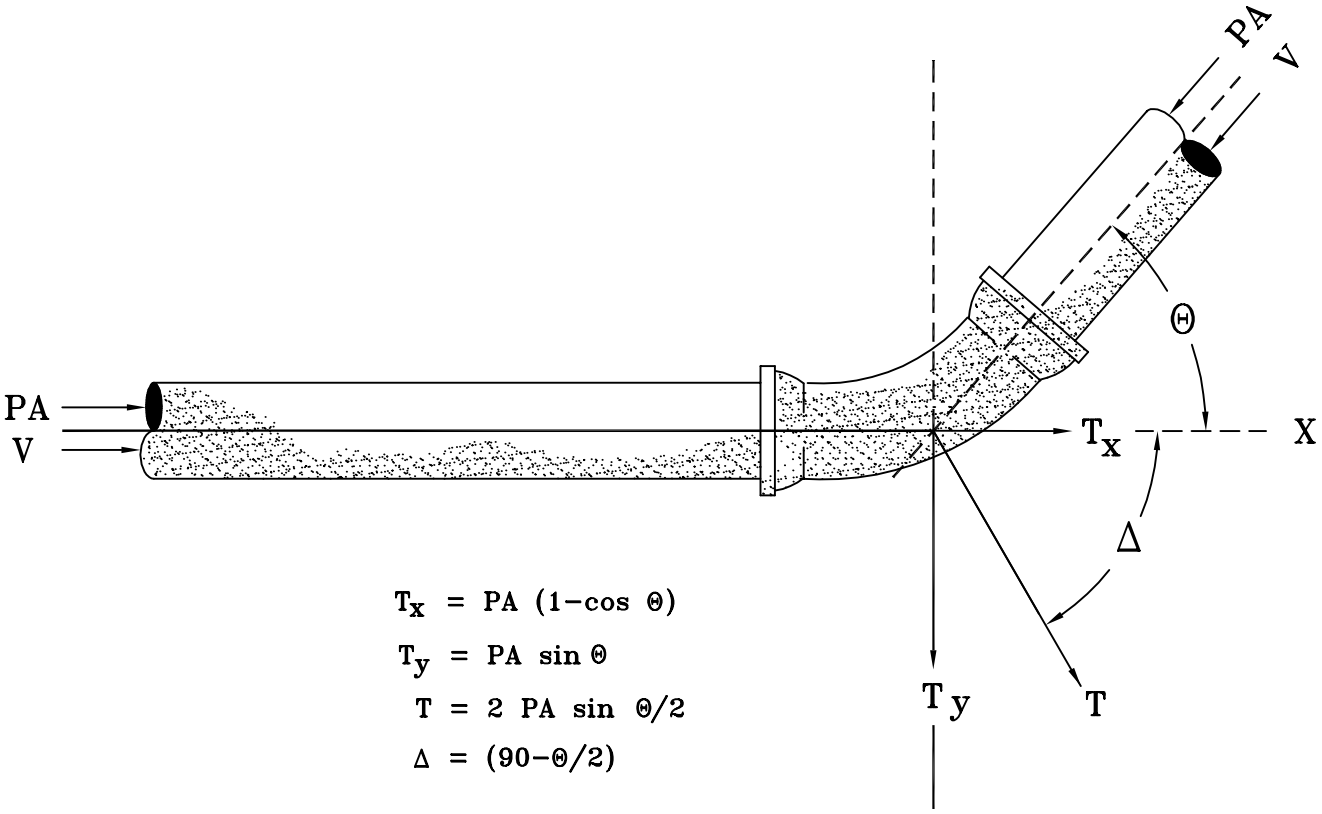
FAULT MAP
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 4



$T_x = PA\ (1-\cos\ \Theta)$

$T_y = PA \sin \Theta$

$T = 2\ PA \sin\ \Theta/2$

$\Delta = (90-\Theta/2)$

Where:

- T is the resultant force on the bend.
- T_x is the component of thrust force in x-direction.
- T_y is the component of thrust force in y-direction.
- P is the maximum sustained pressure.
- A is the pipe cross-sectional area.
- Θ is the bend deflection angle.
- Δ is the angle between T and X-axis.
- V is the fluid velocity.
- D is the inside diameter of conduit.

Sample Calculation:

Given: P = 150 psi, D = 1.0' = 12" For: $\Theta = 90^\circ$

$A = (\pi D^2)/4 = 113.1\ in^2$

Find: $T = 2\ PA \sin\Theta/2 = 2 \times 150 \times 113.1 \times \sin(90^\circ/2)$
$= 23{,}992\ lb = 24.0\ kips$

$T_x = PA\ (1-\cos\ \Theta) = 150 \times 113.1 \times (1-\cos\ 90^\circ)$
$= 16{,}969\ lb = 17.0\ kips$

$T_y = PA \sin \Theta = 150 \times 113.1 \times \sin\ (90^\circ)$
$= 16{,}969\ lb = 17.0\ kips$

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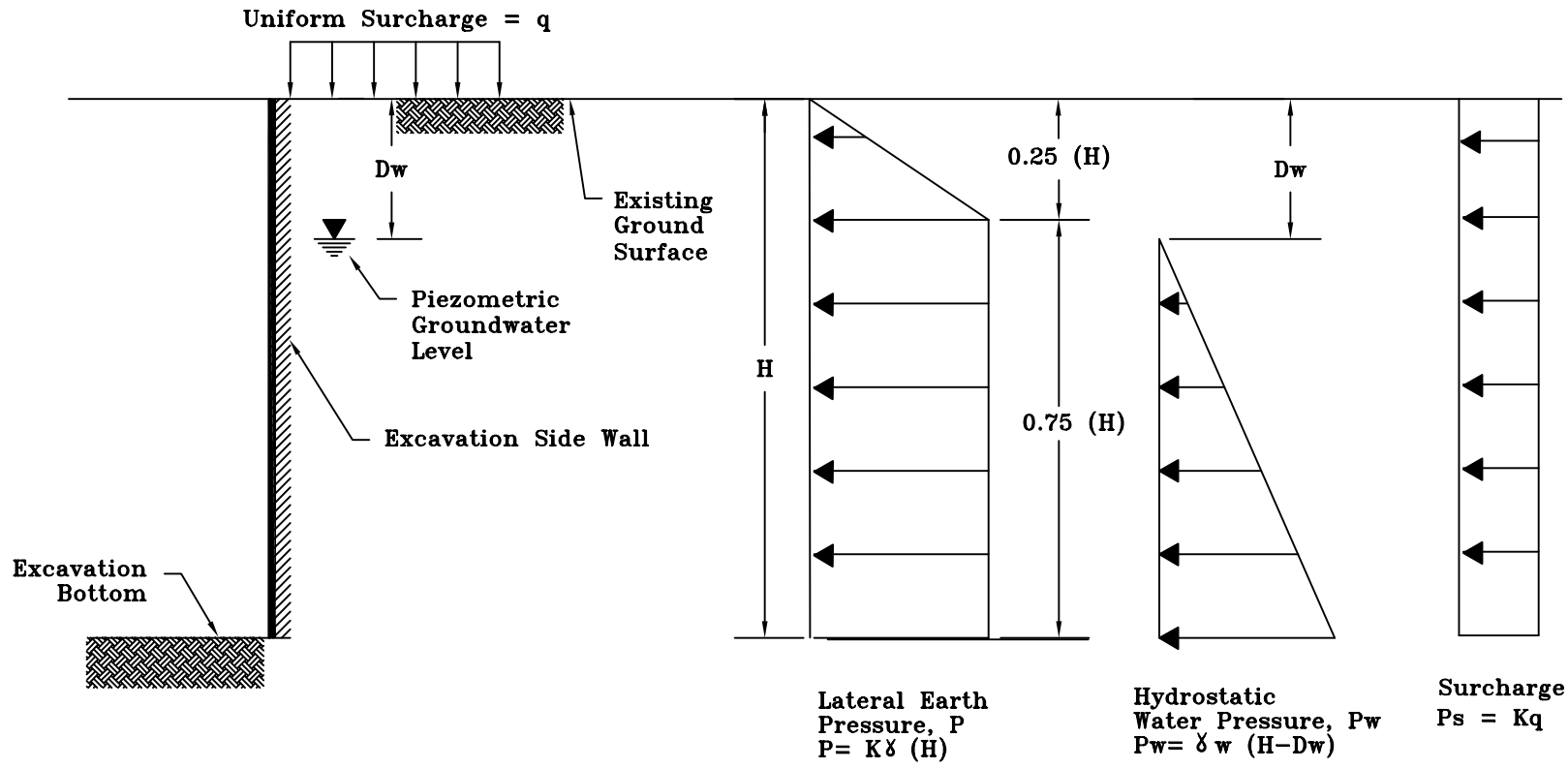
THRUST FORCE ACTING ON A BEND
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS Nos. N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 5



H, (ft) = Depth to Excavation Bottom

Ps, (psf) = Surcharge loading adjacent to Excavation wall

Dw, (ft) = Depth to groundwater below Existing grade

= Zero for temporary excavation

K = Lateral Earth Pressure coefficient

= Ka "active" for short–term conditions (use 0.50)

= Ko "at rest" for long–term conditions (use 1.0)

ɣ, (pcf) = Total unit weight above water table or submerged unit weight below groundwater level

ɣw, (pcf) = Unit weight of water = 62.4 pcf

Note: The pressure diagram shown is not appropriate for design of cantilever walls.

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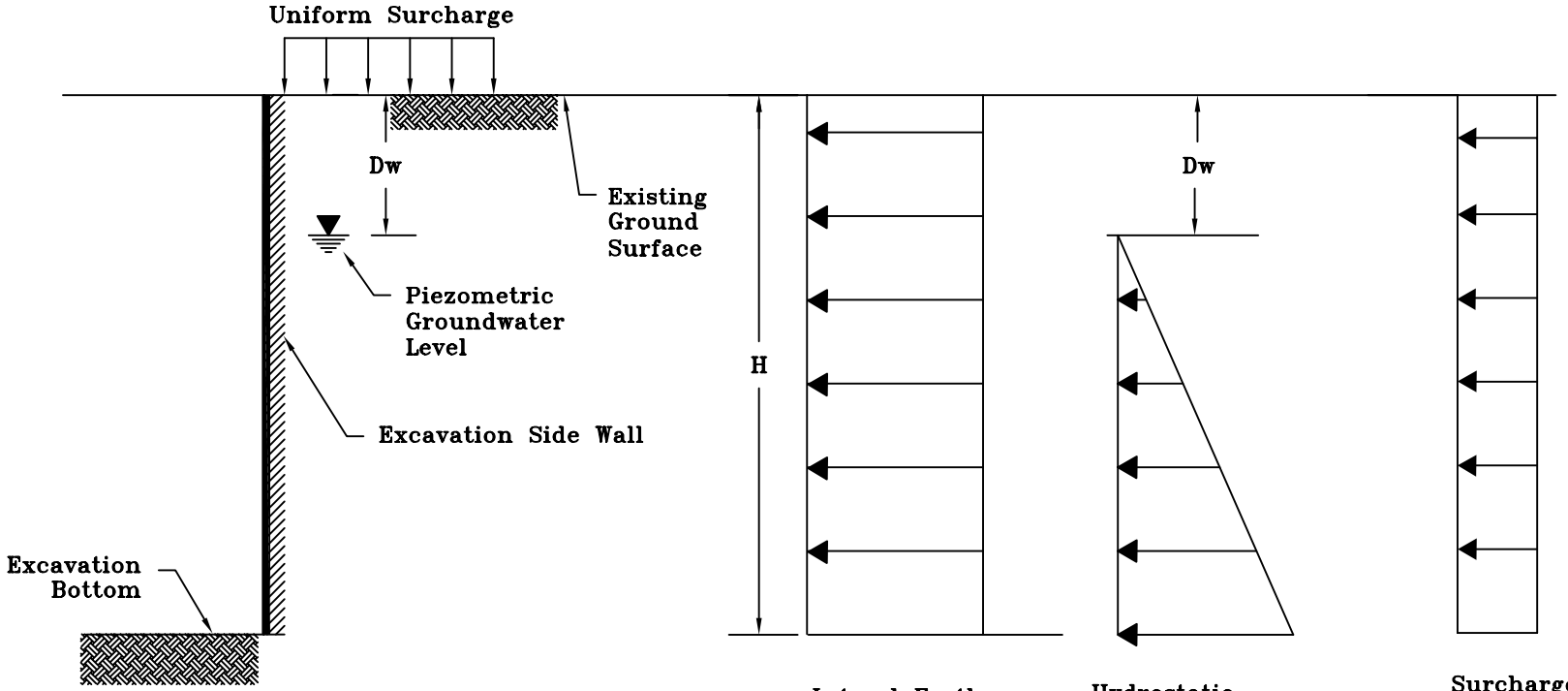
BRACED EXCAVATION
LATERAL EARTH PRESSURE DIAGRAM (CLAY)
WBS No.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 6A



H, (ft) = Depth to Excavation Bottom

Ps, (psf) = Surcharge loading adjacent to Excavation wall

Dw, (ft) = Depth to groundwater below Existing grade

= Zero for temporary excavation

K = Lateral Earth Pressure coefficient

= Ka "active" for short–term conditions (use 0.35)

= Ko "at rest" for long–term conditions (use 0.50)

ɣ, (pcf) = Total unit weight above water table or submerged unit weight below groundwater level

ɣw, (pcf) = Unit weight of water = 62.4 pcf

Note: The pressure diagram shown is not appropriate for design of cantilever walls.

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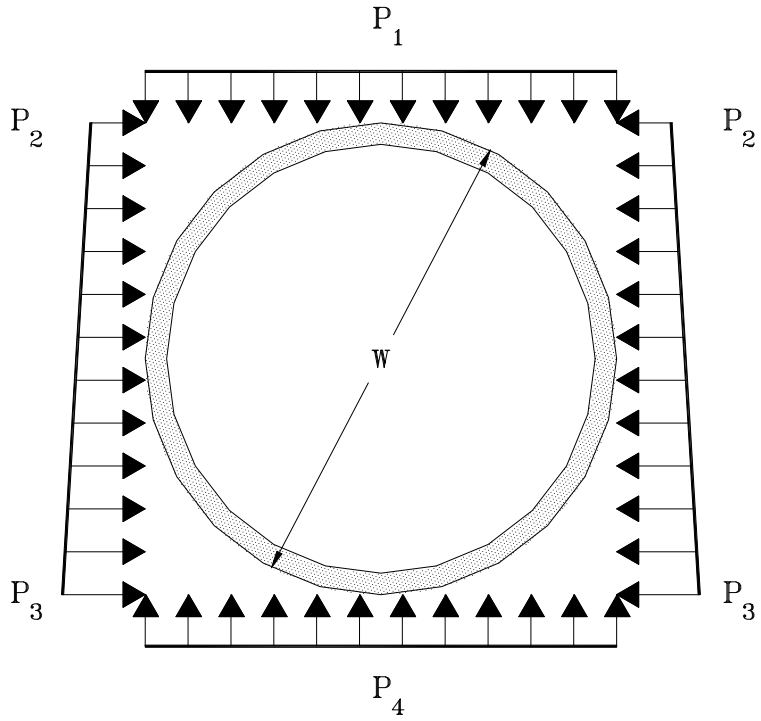
BRACED EXCAVATION
LATERAL EARTH PRESSURE DIAGRAM(SAND/SILT)
WBS No. N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE 6B



For

$D_w \leq H$

$P_1 = \gamma D_w + (H - D_w)(\gamma - \gamma_w) + P_s + (H - D_w)\gamma_w$

$P_2 = [\gamma D_w + (H - D_w)(\gamma - \gamma_w) + P_s]K_o + (H - D_w)\gamma_w$

$P_3 = [\gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s]K_o + (H + W - D_w)\gamma_w$

$P_4 = \gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s + (H + W - D_w)\gamma_w$

For

$H < D_w < H + W$

$P_1 = H\gamma + P_s$

$P_2 = (\gamma H + P_s)K_o$

$P_3 = [\gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s]K_o + (H + W - D_w)\gamma_w$

$P_4 = \gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s + (H + W - D_w)\gamma_w$

For

$D_w \geq (H + W)$

$P_1 = H\gamma + P_s$

$P_2 = (\gamma H + P_s)K_o$

$P_3 = [(H + W)\gamma + P_s]K_o$

$P_4 = (H + W)\gamma + P_s$

Where

P_1, P_2, P_3 = Pressure imposed on pipe, psf

D_w = Depth of groundwater, feet

H = Depth of top of pipe from ground surface, feet

W = Diameter of pipe, feet

γ = Total Unit weight of soil, pcf

γ_w = Unit weight of water, pcf

P_s = Surcharge load, psf

K_o = Coefficient of earth pressure, (1.0 for clays and 0.5 for sands)

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DATE: 01/20/2015	APPROVED BY: ND	PREPARED BY: SS

RIGID PIPE LOADS
WBS NO. N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE 7

APPENDIX A

BORING LOGS AND KEY TO TERMS & SYMBOLS

DRILLING LOG

	County	Harris	Hole	B-1	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/30/2014
Version 3.1	CSJ	0912-71-739	Station	31+34.19	Grnd. Elev.	77.24 ft
			Offset	2.85 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
76.2			PAVEMENT, 5" Asphalt, 7" Cement Stabilized Shells							
			CLAY, Sandy, soft, brown and gray, w/ calcareous nodules 6'-8' (CL)			17	34	19		% Passing #200 Sieve: 65.4
5		4 (6) 6 (6)		5	33.8	16			138	
10		4 (6) 5 (6)								
66.7			CLAY, Lean w/ Sand, soft to stiff, brown and gray (CL)			19	48	32		% Passing #200 Sieve: 76.3
15		8 (6) 7 (6)		14	37.7	19			133	
20		16 (6) 17 (6)								
56.7			CLAY, Lean, very stiff, brown and gray (CL)			19	34	17		% Passing #200 Sieve: 98.2
25		27 (6) 21 (6)		16	31.3	28			124	
49.2										
30										

Remarks: Water was encountered at 24 feet below existing grade during drilling operations; at 16.3 and 15.1 feet after 5 and 10 minutes, respectively. Northing: 13912510.2584 Easting: 3123900.1637 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger:** EE **Organization:** HVJ Associates, Inc.

DRILLING LOG

	County	Harris	Hole	B-2	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/29/2014
Version 3.1	CSJ	0912-71-739	Station	26+54.69	Grnd. Elev.	76.65 ft
			Offset	5.36 RT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Lean w/ Sand, very soft to soft, brown and gray (CL)			17	30	12		% Passing #200 Sieve: 77.8
5		3 (6) 3 (6)		6	36.5	18			132	
10		6 (6) 5 (6)				20	45	29		% Passing #200 Sieve: 83.7
				11	29.6	19			133	
15		8 (6) 8 (6)								
20		7 (6) 6 (6)								
56.2			CLAY, Silty w/ Sand, stiff, reddish brown (CL-ML)			26	29	6		% Passing #200 Sieve: 74.9
25		11 (6) 11 (6)		20	36.1	28			126	
48.7										
30										

Remarks: Water was encountered at 20 feet below existing grade during drilling operations; at 20 feet after 5 and 10 minutes, respectively.
Northing: 13912478.3904 Easting: 3123421.6514 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-3	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/29/2014
Version 3.1	CSJ	0912-71-739	Station	21+06.42	Grnd. Elev.	77.35 ft
			Offset	6.23 RT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Lean w/ Sand, very soft to soft, brown and gray (CL)							
5		2 (6) 3 (6)		5	31.6	16	39	26	136	% Passing #200 Sieve: 78.9
10		3 (6) 5 (6)		10	37.3	18			134	
15		8 (6) 8 (6)								
61.9			CLAY, Fat, stiff, reddish brown (CH)			24	62	42		% Passing #200 Sieve: 88.8
				15	17.4	22			127	
20		11 (6) 12 (6)								
25		14 (6) 13 (6)				24	55	30		% Passing #200 Sieve: 94.7
49.4										
30										

Remarks: Water was encountered at 20 feet below existing grade during drilling operations; at 19.5 and 19 feet after 5 and 10 minutes, respectively. Northing: 13912450.4420 Easting: 3122874.0929 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-4 (PZ-1)	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/28/2014
Version 3.1	CSJ	0912-71-739	Station	16+46.01	Grnd. Elev.	78.90 ft
			Offset	4.13 LT	GW Elev.	66.00 ft

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Fat, soft, brown, w/ gravel at 1' (CH)							
5		9 (6) 11 (6)				16	54	38		% Passing #200 Sieve: 95.6
				7	57	17			133	
10		6 (6) 7 (6)								
15		5 (6) 7 (6)								
63.4			CLAY, Lean w/ Sand, stiff, reddish brown (CL)			18	46	31		% Passing #200 Sieve: 82.2
				15	17.9	25			128	
20		11 (6) 11 (6)								
25		12 (6) 17 (6)				23	29	12		% Passing #200 Sieve: 81.9
50.9										
30										

Remarks: Water was encountered at 25 feet, 11.8 feet, 12.6 feet and 12.9 feet below existing grade during drilling operations, after 24 hours, after 15 days and after 30 days, respectively. Northing: 13912563.2105 Easting: 3124997.6666 WBS No. N-000686-0002-3

Any ground water elevation information provided on this boring log is representative of conditions existing on the day and for the specific location where this information was collected. The actual groundwater elevation may fluctuate due to time, climatic conditions, and/or construction activity.

Driller: PSI **Logger:** EE **Organization:** HVJ Associates, Inc.

DRILLING LOG

	County	Harris	Hole	B-5	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/30/2014
Version 3.1	CSJ	0912-71-739	Station	42+32.97	Grnd. Elev.	77.28 ft
			Offset	1.54 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
76.2			PAVEMENT, 6" Asphalt, 7" Cement Stabilized Shells							
			CLAY, Lean, very soft to stiff, brown and gray (CL)							
				3	27.6	20	36	20	128	% Passing #200 Sieve: 89.0
5		3 (6) 3 (6)								
				7	39.5	18			134	
10		6 (6) 6 (6)								
15		15 (6) 17 (6)								
61.8			CLAY, Fat, stiff to hard, reddish brown (CH)	14	55.8	22	50	31	132	% Passing #200 Sieve: 86.1
20		37 (6) 50 (6)								
25		13 (6) 14 (6)								
						23	55	35		% Passing #200 Sieve: 94.0
49.3										
30										

Remarks: Water was encountered at 21.5 feet below existing grade during drilling operations; at 18.2 and 16.9 feet after 5 and 10 minutes, respectively. Northing: 13912563.2105 Easting: 3124997.6666 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-6	District	Houston
WinCore	Highway	Greens Road	Structure		Date	8/1/2014
Version 3.1	CSJ	0912-71-739	Station	48+29.73	Grnd. Elev.	78.11 ft
			Offset	19.39 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test Lateral Press. (psi)	Triaxial Test Deviator Stress (psi)	Properties MC	Properties LL	Properties PI	Properties Wet Den. (pcf)	Additional Remarks
77.2			PAVEMENT, 5" Asphalt, 6" Cement Stabilized Shells							
			CLAY, Fat w/ Sand, soft, brown and gray, w/ calcareous nodules 6'-11' (CH)							
5		4 (6) 5 (6)				22	55	32		% Passing #200 Sieve: 83.6
				7	25.3	22			130	
10		4 (6) 7 (6)								
64.1			CLAY, Lean w/ Sand, stiff, reddish brown (CL)							
15		11 (6) 13 (6)				15	42	25		% Passing #200 Sieve: 84.0
				15	70.9	15			138	
20		13 (6) 15 (6)								
25		19 (6) 13 (6)								
				20	66.5	18	43	21	133	% Passing #200 Sieve: 84.4
50.1										
30										

Remarks: Water was encountered at 28 feet below existing grade during drilling operations; at 28 and 27.8 feet after 5 and 10 minutes, respectively. Northing: 13912610.4992 Easting: 3125592.8222 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-7 (PZ-2)	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/30/2014
Version 3.1	CSJ	0912-71-739	Station	53+01.06	Grnd. Elev.	78.41 ft
			Offset	7.41 RT	GW Elev.	68.00 ft

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Sandy, very soft, brown and gray (CL)			12	23	9		% Passing #200 Sieve: 63.4
5		3 (6) 4 (6)		7	23.3	18			134	
10		2 (6) 4 (6)								
67.9			CLAY, Fat w/ Sand, soft to stiff, reddish brown (CH)			29	61	36		% Passing #200 Sieve: 80.6
15		8 (6) 11 (6)		15	56.5	17			137	
20		10 (6) 13 (6)				21	53	28		% Passing #200 Sieve: 84.9
25		15 (6) 17 (6)		20	45.4	23			131	
50.4										
30										

Remarks: Water was not encountered during drilling. The 24-hour, 15-day and 30-day piezometer readings were observed at 7.7 feet, 9.5 feet and 10.4 feet below the existing grade. Northing: 13912607.0124 Easting: 3126064.8968. WBS No. N-000686-0002-3

Any ground water elevation information provided on this boring log is representative of conditions existing on the day and for the specific location where this information was collected. The actual groundwater elevation may fluctuate due to time, climatic conditions, and/or construction activity.

Driller: PSI **Logger:** EE **Organization:** HVJ Associates, Inc.

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DRILLING LOG

	County	Harris	Hole	B-8	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/30/2014
Version 3.1	CSJ	0912-71-739	Station	57+32.87	Grnd. Elev.	79.41 ft
			Offset	0.90 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test Lateral Press. (psi)	Triaxial Test Deviator Stress (psi)	Properties MC	Properties LL	Properties PI	Properties Wet Den. (pcf)	Additional Remarks
78.4			PAVEMENT, 5" Asphalt, 7" Cement Stabilized Shells							
			CLAY, Sandy, soft to stiff, brown and gray (CL)							
		6 (6) 10 (6)				15	27	9		% Passing #200 Sieve: 58.1
5				7	41.1	12			141	
		11 (6) 8 (6)								
10										
		10 (6) 12 (6)								
15										
63.9			CLAY, Lean w/ Sand, stiff, reddish brown (CL)			18	47	31		% Passing #200 Sieve: 78.2
				16	37.7	18			136	
		14 (6) 21 (6)								
20										
55.4			CLAY, Lean, very stiff, reddish brown (CL)							
		18 (6) 23 (6)								
25				20	65.2	18	33	16	136	% Passing #200 Sieve: 89.7
51.4										
30										

Remarks: Water was not encountered during drilling. Northing: 13912636.6356 Easting: 3126495.7730 **WBS No.** N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger:** EE **Organization:** HVJ Associates, Inc.

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DRILLING LOG

	County	Harris	Hole	B-9	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/31/2014
Version 3.1	CSJ	0912-71-739	Station	62+89.31	Grnd. Elev.	79.71 ft
			Offset	19.19 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
78.9			PAVEMENT, 5" Asphalt, 5" Cement Stabilized Shells							
			CLAY, Lean, soft to stiff, reddish brown (CL)							
		8 (6) 7 (6)								
5				7	26.4	18	41	27	131	% Passing #200 Sieve: 90.6
		5 (6) 6 (6)								
10										
		10 (6) 11 (6)								
15				14	39.7	19	46	28	132	% Passing #200 Sieve: 85.5
		13 (6) 16 (6)								
20										
59.2			CLAY, Lean w/ Sand, stiff, reddish brown (CL)	18	38.8	17			136	
						18	34	18		% Passing #200 Sieve: 79.7
		16 (6) 17 (6)								
25										
51.7										
30										

Remarks: Water was encountered at 25 feet below existing grade during drilling operations; at 22 and 21.5 feet after 5 and 10 minutes, respectively. Northing: 13912682.3758 Easting: 3127050.6251 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-10	District	Houston
WinCore	Highway	Greens Road	Structure		Date	8/1/2014
Version 3.1	CSJ	0912-71-739	Station	67+47.50	Grnd. Elev.	78.99 ft
			Offset	9.59 RT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test Lateral Press. (psi)	Triaxial Test Deviator Stress (psi)	Properties MC	Properties LL	Properties PI	Properties Wet Den. (pcf)	Additional Remarks
			CLAY, Silty w/ Sand, very soft to soft, dark gray, w/ gravel at 1' (CL-ML)			15	23	7		% Passing #200 Sieve: 76.6
5		2 (6) 2 (6)								
				7	17.8	18			131	
10		7 (6) 8 (6)								
65.			CLAY, Fat, stiff, reddish brown (CH)							
15		12 (6) 13 (6)								
				13	34.8	22	56	38	126	% Passing #200 Sieve: 96.4
20		13 (6) 14 (6)								
				16	36.8	21			130	
55.			CLAY, Lean w/ Sand, stiff, reddish brown, w/ calcareous nodules at 26' (CL)							
25		15 (6) 19 (6)								
						18	31	13		% Passing #200 Sieve: 72.2
51.										
30										

Remarks: Water was encountered at 25 feet below existing grade during drilling operations; at 17.3 and 14.6 feet after 5 and 10 minutes, respectively. Northing: 13912676.2491 Easting: 3127509.6755 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-11	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/31/2014
Version 3.1	CSJ	0912-71-739	Station	72+79.16	Grnd. Elev.	80.29 ft
			Offset	18.29 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
79.4			PAVEMENT, 5" Asphalt, 6" Cement Stabilized Shells							
			CLAY, Sandy, very soft to soft, brown and gray (CL)							
		2 (6) 3 (6)		5	24.3	16			138	
						17	31	16		% Passing #200 Sieve: 50.6
		5 (6) 7 (6)								
		6 (6) 7 (6)								
64.8			CLAY, Lean w/ Sand, soft, reddish brown (CL)			17	30	16		% Passing #200 Sieve: 74.3
		6 (6) 7 (6)								
59.8			CLAY, Fat, stiff, reddish brown (CH)							
		11 (6) 12 (6)				18	57	32		% Passing #200 Sieve: 86.7
52.3				18	73.5	19			136	

Remarks: Water was encountered at 16.5 feet below existing grade during drilling operations; at 14.3 and 13.5 feet after 5 and 10 minutes, respectively. Northing: 13912730.3493 Easting: 3128039.3140 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-12	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/31/2014
Version 3.1	CSJ	0912-71-739	Station	77+55.24	Grnd. Elev.	80.62 ft
			Offset	0.29 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
79.7			PAVEMENT, 5" Asphalt, 6" Cement Stabilized Shells							
			CLAY, Sandy Fat, very soft to soft, reddish brown (CH)			24	51	34		% Passing #200 Sieve: 54.8
5		3 (6) 4 (6)								
				8	39.4	16			134	
10		9 (6) 11 (6)								
15		8 (6) 11 (6)								
65.1			CLAY, Lean w/ Sand, soft to stiff, reddish brown (CL)			18	33	20		% Passing #200 Sieve: 83.4
				14	39.1	17			136	
20		9 (6) 10 (6)								
25		14 (6) 16 (6)				25	39	21		% Passing #200 Sieve: 79.9
52.6										
30										

Remarks: Water was encountered at 19 feet below existing grade during drilling operations; at 15 and 13.3 feet after 5 and 10 minutes, respectively. Northing: 13912732.7915 Easting: 3128515.8399 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-13 (PZ-3)	District	Houston
WinCore	Highway	Greens Road	Structure		Date	8/4/2014
Version 3.1	CSJ	0912-71-739	Station	82+55.12	Grnd. Elev.	80.23 ft
			Offset	28.24 LT	GW Elev.	72.60 ft

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Sandy, soft, brown and gray (CL)							
5		5 (6) 5 (6)				15	37	23		% Passing #200 Sieve: 52.7
10		6 (6) 8 (6)								
15		8 (6) 11 (6)								
64.7			CLAY, Lean w/ Sand, very soft, brown and gray (CL)			22	38	24		% Passing #200 Sieve: 83.1
20		4 (6) 4 (6)		14	28.6	19			133	
56.2			CLAY, Sandy, stiff, reddish brown (CL)							
25		13 (6) 12 (6)								
52.2						20	32	15		% Passing #200 Sieve: 64.2
30										

Remarks: Water was encountered at 13.5 feet, 7.2 feet, 7.4 feet and 7.6 feet below existing grade during drilling operations, after 24 hours, 15 days and 30 days, respectively. Northing: 13912732.7915 Easting: 3128515.8399 WBS No. N-000686-0002-3

Any ground water elevation information provided on this boring log is representative of conditions existing on the day and for the specific location where this information was collected. The actual groundwater elevation may fluctuate due to time, climatic conditions, and/or construction activity.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	B-14	District	Houston
WinCore	Highway	Greens Road	Structure		Date	7/31/2104
Version 3.1	CSJ	0912-71-739	Station	87+67.43	Grnd. Elev.	80.47 ft
			Offset	18.23 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
79.6			PAVEMENT, 4" Asphalt, 6" Cement Stabilized Shells							
			SAND, Clayey, loose, brown (SC)			12	33	17		% Passing #200 Sieve: 28.9
		5 (6) 7 (6)								
5										
75.			CLAY, Sandy, soft, brown (CL)	5	44.6	15			135	% Passing #200 Sieve: 51.0
		8 (6) 10 (6)								
10										
70.			SAND, Clayey, loose, brown (SC)			16	28	10		% Passing #200 Sieve: 35.8
		7 (6) 12 (6)								
15										
		5 (6) 4 (6)								
20										
60.			CLAY, Lean w/ Sand, soft, reddish brown (CL)	13	16.2	18	29	17	132	% Passing #200 Sieve: 83.5
		9 (6) 9 (6)								
25										
52.5				16	30.5	29			124	
30										

Remarks: Water was encountered at 12 feet below existing grade during drilling operations; at 9.3 and 9 feet after 5 and 10 minutes, respectively.
Northing: 13912792.4157 Easting: 3129526.4395 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

	County	Harris	Hole	BR-1	District	Houston
WinCore	Highway	Greens Road	Structure	Bridge	Date	8/5/2014
Version 3.1	CSJ	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
			Offset	19.16 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
76.1			PAVEMENT, 3" Asphalt, 10" Cement Stabilized Shells							
			CLAY, Sandy, soft, dark gray, w/ calcareous nodules 6'-8' (CL)			15	28	13		% Passing #200 Sieve: 64.1
5		7 (6) 9 (6)								
10		6 (6) 6 (6)								
66.7			CLAY, Lean w/ Sand, stiff, brown and gray (CL)	10	19.8	19	36	23	131	% Passing #200 Sieve: 71.8
15		12 (6) 16 (6)								D50: 0.047mm
60.2			CLAY, Sandy, stiff to very stiff, reddish gray (CL)			13	38	23		% Passing #200 Sieve: 63.7
20		18 (6) 19 (6)		18	57.4	21			127	
25		18 (6) 23 (6)								D50: 0.045mm
50.2			CLAY, Fat, stiff to very stiff, reddish gray (CH)			21	59	36		% Passing #200 Sieve: 97.4
30		11 (6) 14 (6)								

Remarks: Water was encountered at 23.8 feet below existing grade during drilling operations; at 23.6 feet after 5 and 10 minutes. Northing: 13912557.7397 Easting: 3124530.2219 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

WinCore Version 3.1	County	Harris	Hole	BR-1	District	Houston
	Highway	Greens Road	Structure	Bridge	Date	8/5/2014
	CSJ	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
			Offset	19.16 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	LL	PI	Wet Den. (pcf)	Additional Remarks
			CLAY, Fat, stiff to very stiff, reddish gray (CH)	25	35.7	27			126	
35		38 (6) 34 (6)								
41.7			SILT, With sand, compact, brown (ML)							
40		33 (6) 40 (6)				20				% Passing #200 Sieve: 73.2
45		23 (6) 19 (6)								
50		22 (6) 23 (6)								
26.7			CLAY, Fat, stiff, brown (CH)	32	19.1	29	63	30	119	% Passing #200 Sieve: 98.1
55		14 (6) 23 (6)								
21.7			SILT, With sand, slightly compact to dense, brown (ML)							
60		50 (3) 50 (4)								

Remarks: Water was encountered at 23.8 feet below existing grade during drilling operations; at 23.6 feet after 5 and 10 minutes. Northing: 13912557.7397 Easting: 3124530.2219 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

DRILLING LOG

WinCore Version 3.1	County	Harris	Hole	BR-1	District	Houston
	Highway	Greens Road	Structure	Bridge	Date	8/5/2014
	CSJ	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
			Offset	19.16 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test Lateral Press. (psi)	Triaxial Test Deviator Stress (psi)	Properties MC	Properties LL	Properties PI	Properties Wet Den. (pcf)	Additional Remarks
			SILT, With sand, slightly compact to dense, brown (ML)			20				% Passing #200 Sieve: 75.9
65		13 (6) 11 (6)								
11.7			CLAY, Silty w/ Sand, very stiff, brown and gray (CL-ML)							
70		20 (6) 23 (6)		42	66	19	22	4	131	% Passing #200 Sieve: 78.3
75		21 (6) 23 (6)								
80		20 (6) 27 (6)								
-3.3										
85										
90										

Remarks: Water was encountered at 23.8 feet below existing grade during drilling operations; at 23.6 feet after 5 and 10 minutes. Northing: 13912557.7397 Easting: 3124530.2219 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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DRILLING LOG

WinCore Version 3.1	County	Harris	Hole	BR-2	District	Houston
	Highway	Greens Road	Structure	Bridge	Date	8/6/2014
	CSJ	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
			Offset	2.43 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
75.6			PAVEMENT, 3" Asphalt, 10" Cement Stabilized Shells							
			CLAY, Sandy, soft to stiff, brown and gray (CL)							
		13 (6) 13 (6)				12	30	10		% Passing #200 Sieve: 61.1
				7	54.5	14			136	
		5 (6) 6 (6)								
		14 (6) 17 (6)								D50: 0.047mm
61.2			CLAY, Lean, stiff to very stiff, reddish brown, w/ sand at 16' (CL)	14	33.2	14	44	25	129	% Passing #200 Sieve: 79.9
		20 (6) 17 (6)								
		23 (6) 21 (6)								D50: 0.045mm
				21	12.9	28	43	21	126	% Passing #200 Sieve: 91.5
		12 (6) 13 (6)								

Remarks: Water was encountered at 24 feet below existing grade during drilling operations; at 23.6 and 20.6 feet after 5 and 10 minutes, respectively. Northing: 13912534.7974 Easting: 3124404.8736 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

DRILLING LOG

	County	Harris	Hole	BR-2	District	Houston
WinCore	Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Version 3.1	CSJ	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
			Offset	2.43 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	Properties: LL	Properties: PI	Properties: Wet Den. (pcf)	Additional Remarks
			CLAY, Lean, stiff to very stiff, reddish brown, w/ sand at 16' (CL)							
35		11 (6) 11 (6)								
40		15 (6) 16 (6)								
36.2			CLAY, Silty, stiff, reddish brown (CL-ML)			27	25	7		% Passing #200 Sieve: 95.9
45		12 (6) 23 (6)		30	33.3	23			122	
50		17 (6) 17 (6)								
26.2			CLAY, Fat, stiff to very stiff, reddish brown (CH)			29	58	28		% Passing #200 Sieve: 98.9
55		21 (6) 24 (6)								
				34	48.5	28	60	30	125	% Passing #200 Sieve: 98.5
60		24 (6) 20 (6)								

Remarks: Water was encountered at 24 feet below existing grade during drilling operations; at 23.6 and 20.6 feet after 5 and 10 minutes, respectively. Northing: 13912534.7974 Easting: 3124404.8736 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

DRILLING LOG

	County	Harris	Hole	BR-2	District	Houston
WinCore	Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Version 3.1	CSJ	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
			Offset	2.43 LT	GW Elev.	N/A

Elev. (ft)	LOG	Texas Cone Penetrometer	Strata Description	Triaxial Test: Lateral Press. (psi)	Triaxial Test: Deviator Stress (psi)	Properties: MC	LL	PI	Wet Den. (pcf)	Additional Remarks
			CLAY, Fat, stiff to very stiff, reddish brown (CH)							
65		9 (6) 12 (6)								
				38	62.3	22	50	25	133	% Passing #200 Sieve: 87.3
70		14 (6) 16 (6)								
75		41 (6) 26 (6)								
						29	56	29		% Passing #200 Sieve: 93.9
80		27 (6) 29 (6)								
-3.8										
85										
90										

Remarks: Water was encountered at 24 feet below existing grade during drilling operations; at 23.6 and 20.6 feet after 5 and 10 minutes, respectively. Northing: 13912534.7974 Easting: 3124404.8736 WBS No. N-000686-0002-3

The ground water elevation was not determined during the course of this boring.

Driller: PSI **Logger: EE** **Organization: HVJ Associates, Inc.**

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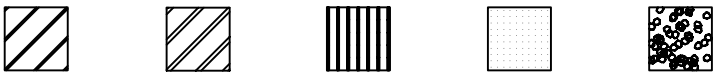
SOIL SYMBOLS

Soil Types



SOIL GRAIN SIZE

Classification	Particle Size	Particle Size or Sieve No. (U.S. Standard)
Clay	< 0.005 mm	< 0.002 mm
Silt	0.005 - 0.074 mm	0.002 mm - #200 sieve
Sand	0.074 - 4.75 mm	#200 sieve - #4 sieve
Gravel	4.75 - 75 mm	#4 sieve - 3 in.
Cobble	75 - 200 mm	3 in. - 8 in.
Boulder	> 200 mm	> 8 in.

DENSITY OF COHESIONLESS SOILS

Density of Cohesionless Soil	TxDOT Cone Penetrometer Blow Count
Very Loose	0 - 8
Loose	8 - 20
Slightly Compact	20 - 40
Compact	40 - 80
Dense	80 - 100 (5")
Very Dense	100 (5") - 100 (0")

CONSISTENCY OF COHESIVE SOILS

Consistency	Deviator Stress Strength (psi)	TxDOT Cone Penetrometer Blow Count
Very Soft	0 - 3.48	0 - 8
Soft	3.48 - 13.9	8 - 20
Stiff	13.9 - 27.8	20 - 40
Very Stiff	27.8 - 55.6	40 - 80
Hard	> 55.6	80 - 100 (5")
Very Hard		100 (5") - 100 (0")

TxDOT Cone Penetrometer

Blows required to penetrate each of two consecutive 6-inch increments
If more than 50 blows are required, driving is discontinued and penetration at 50 blows is noted

TERMS DESCRIBING SOIL STRUCTURE

Slickensided	Fracture planes appear polished or glossy, sometimes striated
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Inclusion	Small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Parting	Inclusion less than 1/4 inch thick extending through the sample
Seam	Inclusion 1/4 inch to 3 inches thick extending through the sample
Layer	Inclusion greater than 3 inches thick extending through the sample
Laminated	Soil sample composed of alternating partings of different soil type
Stratified	Soil sample composed of alternating seams or layers of different soil type
Intermixed	Soil sample composed of pockets of different soil type and laminated or stratified structure is not evident
Calcareous	Having appreciable quantities of calcium carbonate
Ferrous	Having appreciable quantities of iron
Nodule	A small mass of irregular shape

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
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KEY TO TERMS AND SYMBOLS
USED ON BORING LOGS

PROJECT NO.: HG0519680

DRAWING NO.: PLATE A-17

HVJ ASSOCIATES
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Houston, Texas 77072-1010
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281.933.7293 Fax

LOG OF BORING DP-1

PROJECT: Greens Road

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/5/2014

SURFACE ELEVATION 74.5 Feet

LOCATION

Northing: 13911533.0234
Easting: 3124204.8841

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	CL	SANDY LEAN CLAY, stiff to very stiff, medium plasticity, brown and gray, moist w/ calcareous nodules and ferrous	P=2.0										
			P=2.0										
5			P=3.0										
			P=2.75	118	0.85	14.78	7	16	38	20	18	59.5	Pinhole: ND1 Non Dispersive Crumb: 1 Non Dispersive 10'-12'
			P=2.5										
10	CL	LEAN CLAY WITH SAND, very stiff to hard, medium plasticity, brown and gray, moist w/ sand at 16'	P=3.0					17	33	23	10	84.5	
			P=4.5	121	2.25	14.99	12	14	36	16	20	85.0	c' = 100 psf, ϕ' = 28.3°, c_{cu} = 180 psf, ϕ_{cu} = 24.9°
15			P=4.5										
			P=3.25	110	1.22	10.2	16	18	35	20	15	83.3	
			P=4.5										
20													
	CH	FAT CLAY, very stiff to hard, high plasticity, reddish brown, moist	P=4.5	105	1.38	3.47	22	25	58	29	29	98.2	
25		**Bottom of boring at 25'**											

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Groundwater was not encountered during drilling operations. The 24-hour water level reading was observed to be 8.5 feet.

Sample Key: ☒ SPT ▨ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-18

HVJ ASSOCIATES
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LOG OF BORING DP-2(PZ-4)

PROJECT: Greens Road

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/5/2014

SURFACE ELEVATION 74.8 Feet

LOCATION

Northing: 13911544.1028
Easting: 3124298.5409

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	CL	SANDY LEAN CLAY, stiff to very stiff, medium plasticity, brown and gray, moist w/ calcareous nodules and ferrous	P=3.5					16	36	18	18	67.5	
			P=2.75										
5			P=1.5										
			P=1.25										Crumb: 1 Non Dispersive
	CH	FAT CLAY WITH SAND, very stiff, high plasticity, brown and gray, moist	P=2.25					17	57	26	31	78.8	
10	CL	LEAN CLAY, stiff to hard, medium to high plasticity, reddish brown, moist	P=2.5						43	14	29		
			P=4.25	117	1.78	11.9	12	17					
15			P=4.5										
			P=4.5										Crumb: 1 Non Dispersive
20			P=4.5	111	0.96	15.0	17	20	39	20	19	95.5	
			P=4.5										
25		**Bottom of boring at 25'**											

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Groundwater was not encountered during drilling operations. The 24-hour and 30-day water level reading was observed to be 11.3 feet and 14.3, respectively.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-19

HVJ ASSOCIATES
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281.933.7293 Fax

LOG OF BORING DP-3

PROJECT: Greens Road

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/5/2014

SURFACE ELEVATION 74.1 Feet

LOCATION

Northing: 13911548.8844
Easting: 3124380.63

DEPTH (ft.)	SAMPLES	USC	WATER LEVEL	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		CL		SANDY LEAN CLAY, stiff to hard, high plasticity, brown and gray, moist	P=3.0										
					P=4.5	116	2.11	9.16	3	13	35	14	21	69.2	
5					P=1.75										Crumb: 1 Non Dispersive
					P=2.75										
		CL		LEAN CLAY WITH SAND, stiff to hard, high plasticity, brown and gray, moist w/ sand at 9'	P=2.0	108	0.59	6.29	9	17	45	15	30	78.0	
10					P=3.25										
					P=4.5										
15					P=1.75										
					P=4.5	114	1.83	15.03	16	19	44	16	28	84.4	
		CL		LEAN CLAY, hard, high plasticity, brown and gray	P=4.5					21	44	16	28	90.7	18'-20' c' = 650 psf, ø' = 22.2°, c_{cu} = 1370 psf, $ø_{cu}$ = 15.7°
20															
		CH		FAT CLAY, very stiff to hard, high plasticity, reddish brown, moist	P=4.5	104	1.31	2.80	22	24	60	24	36	98.1	
25				**Bottom of boring at 25'**											

Natural Moisture Content and Atterberg Limits (Plastic Limit, Moisture Content, Liquid Limit; 20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations: Groundwater was not encountered during drilling operations. The 24 hour water level reading was observed to be 14 feet.
Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-20

HVJ ASSOCIATES
6120 S. Dairy Ashford Drive
Houston, Texas 77072
Phone (281)-933-7388
Fax (281)-933-7293

LOG OF BORING BR-1

PROJECT: Greens Road Houston

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE: 8/5/2014

SURFACE ELEVATION: 77.2 Feet

LOCATION

Northing: 13912557.7397
Easting: 3124530.2219

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	Material Description	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		Pavement: 3" Asphalt, 10" Cement Stabilized Shells											
	CL	SANDY LEAN CLAY (CL), firm, medium plasticity, dark gray, w/ calcareous nodules 6'-8', moist	P=0.75					15	28	15	13	64.1	
5			P=0.75										
10	CL	LEAN CLAY WITH SAND (CL), stiff to very stiff, high plasticity, brown and gray, moist	P=1.75	110	0.71	11.19	10	19	36	13	23	71.8	
			P=3.5										
15			P=1.5										
	CL	SANDY LEAN CLAY (CL), very stiff to hard, high plasticity, reddish gray, moist						13	38	15	23	63.7	
20			P=4.5	105	2.07	12.24	18	21					
			P=4.5										
25			P=3.75										
	CH	FAT CLAY (CH), very stiff to hard, high plasticity, reddish gray, moist	P=4.0					21	59	23	36	97.4	
30			P=3.5										
			P=4.5	100	1.29	14.63	25	27					
35	ML	SILT WITH SAND (ML), dense, brown, wet											

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Water was encountered at 23.8 feet below existing grade during drilling operations; at 23.6 feet after 5 and 10 minutes.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-21

HVJ ASSOCIATES
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LOG OF BORING BR-1

PROJECT: Greens Road
Houston

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/5/2014

SURFACE ELEVATION 77.2 Feet

LOCATION

Northing: 13912557.7397
Easting: 3124530.2219

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
40			N=39					20				73.2	
45			P=0.75										
50	CH	FAT CLAY (CH), stiff to very stiff, high plasticity, brown, moist	P=1.5 P=2.75	92	0.69	14.93	32	29	63	33	30	98.1	
55	ML	SILT WITH SAND (ML), dense, brown, wet	N=50										
60			N=30					20				75.9	
65	CL ML	SILTY CLAY (CL-ML), very stiff to hard, brown and gray, moist											
70			N=22										
			P=3.25	110	2.37	10.79	42	19	22	18	4	78.3	
75			P=3.0 P=4.5										

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations: Water was encountered at 23.8 feet below existing grade during drilling operations; at 23.6 feet after 5 and 10 minutes.
Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-21

HVJ ASSOCIATES
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Fax (281)-933-7293

LOG OF BORING BR-2

PROJECT: Greens Road Houston

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/6/2015

SURFACE ELEVATION 76.7 Feet

LOCATION

Northing: 13912534.7974
Easting: 3124404.8736

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		Pavement: 3" Asphalt, 10" Cement Stabilized Shells											
	CL	SANDY LEAN CLAY, very stiff to hard, slight plasticity, brown and gray, moist											
5			P=4.5	120	1.96	7.12	7	12 14	30	20	10	61.1	
			P=3.75										
10			P=3.5										
15	CL	LEAN CLAY (CL), firm to hard, high plasticity, reddish brown, w/ sand at 16', moist	P=3.5	114	1.19	15.02	14	14	44	19	25	79.9	
			P=3.75										
20			P=1.75										
25			P=3.5	99	0.47	1.30	21	28	43	22	21	91.5	
30			P=4.25										
35			N=47										

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Water was encountered at 24 feet below existing grade during drilling operations; at 23.6 and 20.6 feet after 5 and 10 minutes, respectively.

Sample Key: ☒ SPT ☐ Shelby Tube ▨ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-22

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LOG OF BORING BR-2

PROJECT: Greens Road Houston

PROJECT NO.: HG0519680 BORING TYPE: FLIGHT AUGER

DATE 8/6/2015

SURFACE ELEVATION 76.7 Feet

LOCATION

Northing: 13912534.7974
Easting: 3124404.8736

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
40	CL ML	SILTY CLAY (CL-ML), very stiff to hard, slight plasticity, reddish brown, moist	N=24					27	25	18	7	95.9	
45			P=4.5										
			P=4.5	99	1.20	2.73	30	23					
50	CH	FAT CLAY (CH), very stiff to hard, high plasticity, reddish brown, moist	P=4.5					29	58	30	28	98.9	
			P=4.5										
55			P=4.5										
			P=4.5	98	1.75	1.90	34	28	60	30	30	98.5	
60			P=4.0										
65			P=4.5										
			P=2.5	109	2.24	11.63	38	22	49	24	25	87.3	
70			P=3.5										
75			N=23					29	56	29	27	93.9	
			P=4.5										

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: Water was encountered at 24 feet below existing grade during drilling operations; at 23.6 and 20.6 feet after 5 and 10 minutes, respectively.

Sample Key: ☒ SPT ☐ Shelby Tube ▨ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:

PLATE A-22

SOIL SYMBOLS

Soil Types


Clay


Silt


Sand


Gravel

Modifiers


Clayey


Silty


Sandy


Cemented

Construction Materials


Asphaltic Concrete


Stabilized Base


Fill or Debris


Portland Cement Concrete

SAMPLER TYPES


Thin Walled Shelby Tube


No Recovery


Split Barrel


Core


Liner Tube


Jar Sample

WATER LEVEL SYMBOLS

Groundwater level after drilling in open borehole or piezometer


Groundwater level determined during drilling operations

SOIL GRAIN SIZE

Classification	Particle Size	Particle Size or Sieve No. (U.S. Standard)
Clay	< 0.002 mm	< 0.002 mm
Silt	0.002 - 0.075 mm	0.002 mm - #200 sieve
Sand	0.075 - 4.75 mm	#200 sieve - #4 sieve
Gravel	4.75 - 75 mm	#4 sieve - 3 in.
Cobble	75 - 200 mm	3 in. - 8 in.
Boulder	> 200 mm	> 8 in.

DENSITY OF COHESIONLESS SOILS

Descriptive Term	Penetration Resistance "N" * Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

CONSISTENCY OF COHESIVE SOILS

Consistency	Undrained Shear Strength (tsf)	Penetration Resistance "N" * Blows/Foot
Very Soft	0 - 0.125	0 - 2
Soft	0.125 - 0.25	2 - 4
Firm	0.25 - 0.5	4 - 8
Stiff	0.5 - 1.0	8 - 16
Very Stiff	1.0 - 2.0	16 - 32
Hard	> 2.0	> 32

PENETRATION RESISTANCE

3/6	Blows required to penetrate each of three consecutive 6-inch increments per ASTM D-1586 *
50/4"	If more than 50 blows are required, driving is discontinued and penetration at 50 blows is noted
0/18"	Sampler penetrated full depth under weight of drill rods and hammer

* The N value is taken as the blows required to penetrate the final 12 inches

TERMS DESCRIBING SOIL STRUCTURE

Slickensided	Fracture planes appear polished or glossy, sometimes striated
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Inclusion	Small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Parting	Inclusion less than 1/4 inch thick extending through the sample
Seam	Inclusion 1/4 inch to 3 inches thick extending through the sample
Layer	Inclusion greater than 3 inches thick extending through the sample
Laminated	Soil sample composed of alternating partings of different soil type
Stratified	Soil sample composed of alternating seams or layers of different soil type
Intermixed	Soil sample composed of pockets of different soil type and laminated or stratified structure is not evident
Calcareous	Having appreciable quantities of calcium carbonate
Ferrous	Having appreciable quantities of iron
Nodule	A small mass of irregular shape

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KEY TO TERMS AND SYMBOLS
USED ON BORING LOGS DP-1 through DP-3

PROJECT NO.: HG0519680

DRAWING NO.: PLATE A-21

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

Project: Greens Road from Aldine Westfield to JFK
Location: Houston, Texas
Number: HG0519680
WBS No. N-000686-0002-3

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)
B-1	3	34	15	19	65.4	17		
	6					16	138	1.2
	11	48	16	32	76.3	19		
	18					19	133	1.4
	21	34	17	17	98.2	19		
	26					28	124	1.1
B-2	3	30	18	12	77.8	17		
	7					18	132	1.3
	11	45	16	29	83.7	20		
	13					19	133	1.1
	21	29	23	6	74.9	26		
	26					28	126	1.3
B-3	6	39	13	26	78.9	16	136	1.1
	11					18	134	1.3
	16	62	20	42	88.8	24		
	18					22	127	0.6
	26	55	25	30	94.7	24		
B-4	6	54	16	38	95.6	16		
	8					17	133	2.1
	16	46	15	31	82.2	18		
	17					25	128	0.6
	26	29	17	12	81.9	23		
B-5	3	36	16	20	89.0	20	128	1.0
	8					18	134	1.2
	16	50	19	31	86.1	22	132	2.0
	26	55	20	35	94.0	23		
B-6	6	55	23	32	83.6	22		
	8					22	130	0.9
	16	42	17	25	84.0	15		

Project: Greens Road from Aldine Westfield to JFK
Location: Houston, Texas
Number: HG0519680
WBS No. N-000686-0002-3

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)
	17					15	138	2.6
	26	43	22	21	86.4	18	133	2.4
B-7	3	23	14	9	63.4	12		
	8					18	134	0.8
	11	61	25	36	80.6	29		
	17					17	137	2.0
	21	53	25	28	89.9	21		
	23					23	131	1.6
B-8	6	27	18	9	58.1	15		
	8					12	141	1.5
	16	47	16	31	78.2	18		
	18					18	136	1.4
	26	33	17	16	89.7	18	136	2.3
B-9	8	41	14	27	90.6	18	131	1.0
	16	46	18	28	85.5	19	132	1.4
	21					17	136	1.4
	23	34	16	18	79.7	18		
B-10	1	23	16	7	76.6	15		
	8					18	131	0.6
	16	56	18	38	96.4	22	126	1.3
	22					21	130	1.3
	26	31	18	13	72.2	18		
B-11	6					16	138	0.9
	8	31	15	16	47.6	17		
	16	30	14	16	74.3	17		
	26	57	25	32	86.7	18		
	28					19	136	2.6
B-12	3	51	17	34	54.8	24		
	9					16	134	1.4

Project: Greens Road from Aldine Westfield to JFK
Location: Houston, Texas
Number: HG0519680
WBS No. N-000686-0002-3

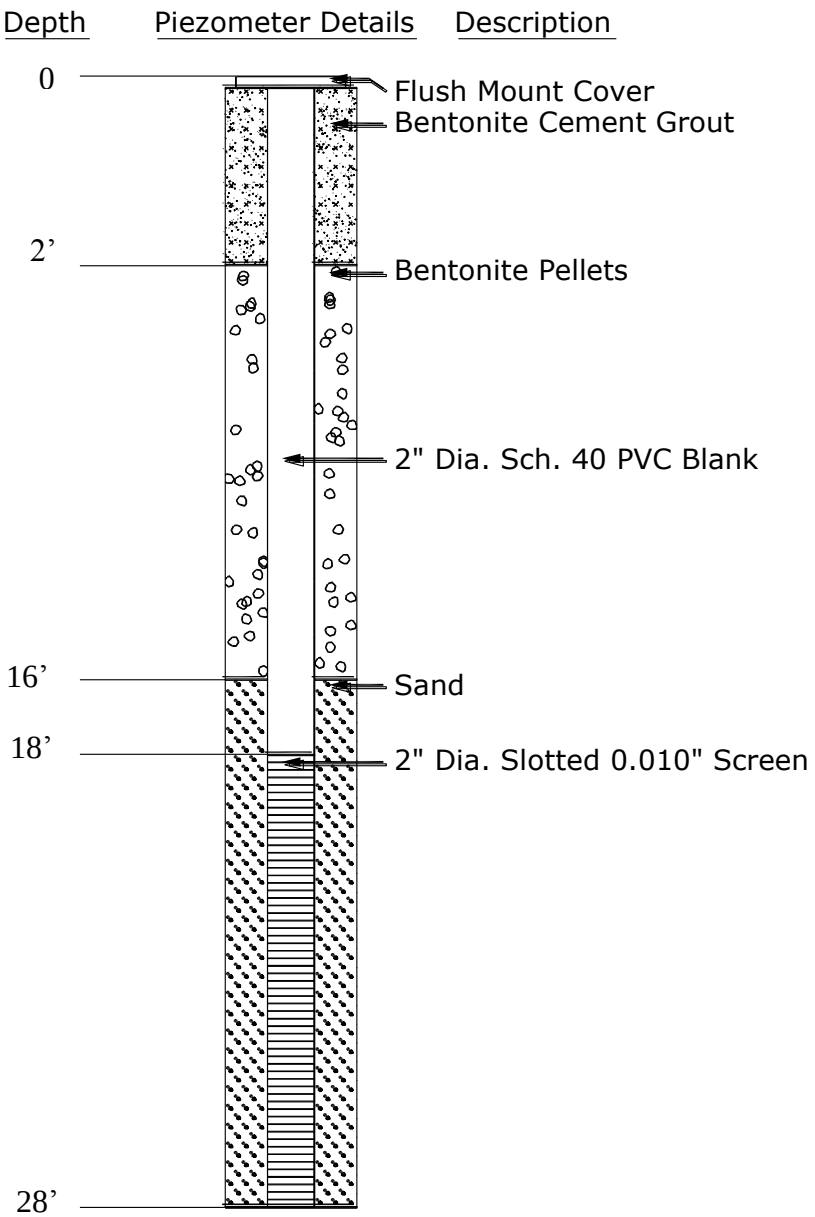
Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)
	18	33	13	20	83.4	18		
	19					17	136	1.4
	26	39	18	21	79.9	25		
B-13	6	37	14	23	42.7	15		
	18	38	14	24	83.1	22		
	21					19	133	1.0
	28	32	17	15	64.2	20		
B-14	3	33	16	17	28.9	12		
	6					15	135	1.6
	11	28	18	10	35.8	16		
	21	29	12	17	83.5	18	132	0.6
	28					29	124	1.1
BR-1	3	28	15	13	64.1	15		
	11	36	13	23	71.8	19	131	0.7
	18	38	15	23	63.7	13		
	21					21	127	2.1
	28	59	23	36	97.4	21		
	33					27	126	1.3
	41				73.2	20		
	51	63	33	30	98.1	29	119	0.7
	61				75.9	20		
	73	22	18	4	78.3	19	131	2.4
BR-2	6	30	20	10	61.1	12		
	8					14	136	2.0
	16	44	19	25	79.9	14	129	1.2
	28	43	22	21	91.5	28	126	0.5
	41	25	18	7	95.9			
	48					23	122	1.2
	51	58	30	28	98.9	29		

Project: Greens Road from Aldine Westfield to JFK
Location: Houston, Texas
Number: HG0519680
WBS No. N-000686-0002-3

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)
	58	60	30	30	98.5	28	125	1.7
	67	50	25	25	87.3	22	133	2.2
	76	56	27	29	93.9	29		
DP-1	6	38	20	18	59.6	16	137	0.9
	12	36	16	20	85.0	14	138	2.3
	17	35	20	15	83.3	18	130	1.2
	23	58	29	29	98.2	25	131	1.4
DP-2	1	36	18	18	67.5	16		
	9	57	26	31	78.8	17		
	13					17	137	1.8
	19	39	20	19	95.5	20	133	1.0
DP-3	3	35	14	21	69.2	13	131	2.1
	9	45	15	30	78.0	17	126	0.6
	17	44	16	28	84.4	19	136	1.8
	24	60	24	36	98.1	24	129	1.3
Total		**67**	**67**	**67**	**69**	**101**	**58**	**58**

APPENDIX C

PIEZOMETER INSTALLATION RECORDS



Water Level Readings

Date	Depth (ft.)	Elev. (ft.)
7/29/14	11.8’	67.1’
8/13/14	12.6’	66.3’
8/28/14	12.9’	66’

NOTES:

- Piezometer was installed on 7/28/14.
- See Plate 2 for boring location

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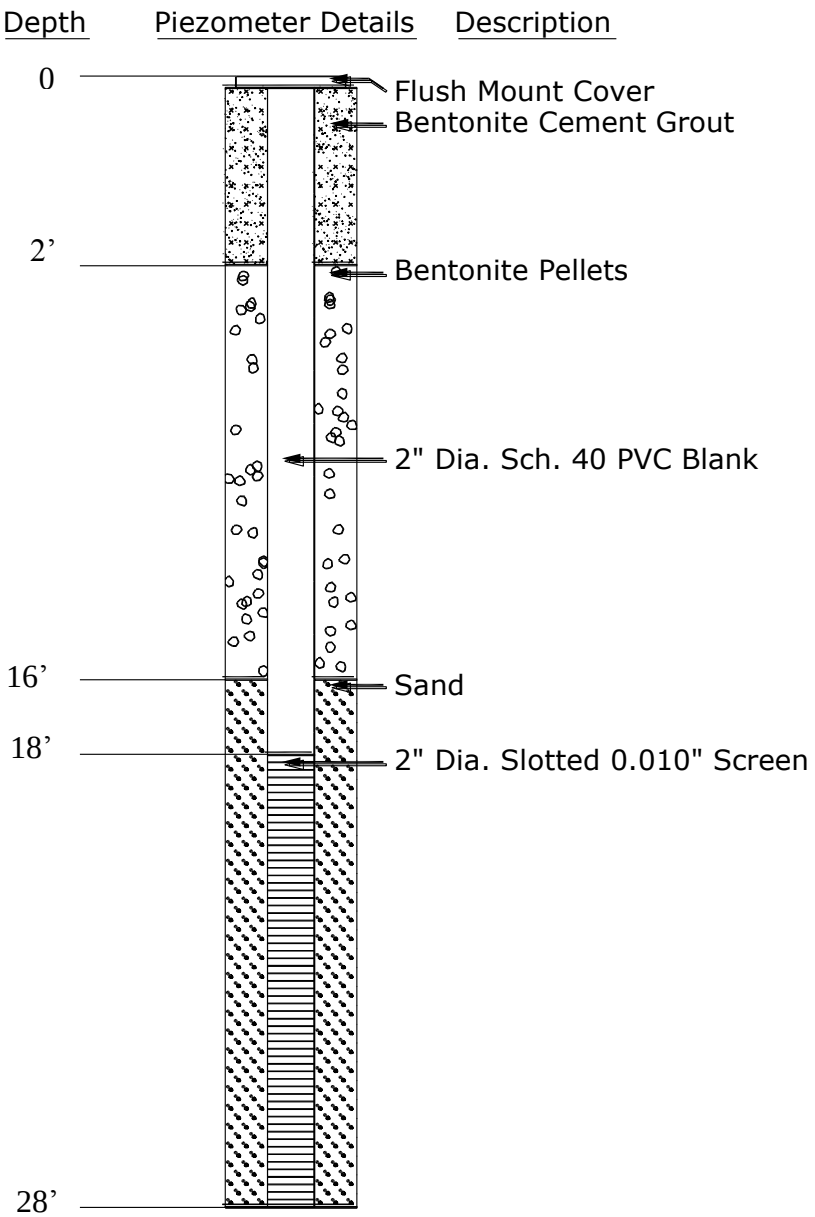
PIEZOMETER INSTALLATION REPORT
PIEZOMETER NO. PZ-1 (B-4)

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE C-1



Water Level Readings

Date	Depth (ft.)	Elev. (ft.)
7/31/14	7.7’	70.7
8/16/14	9.9	68.5
9/30/14	10.4	68.0

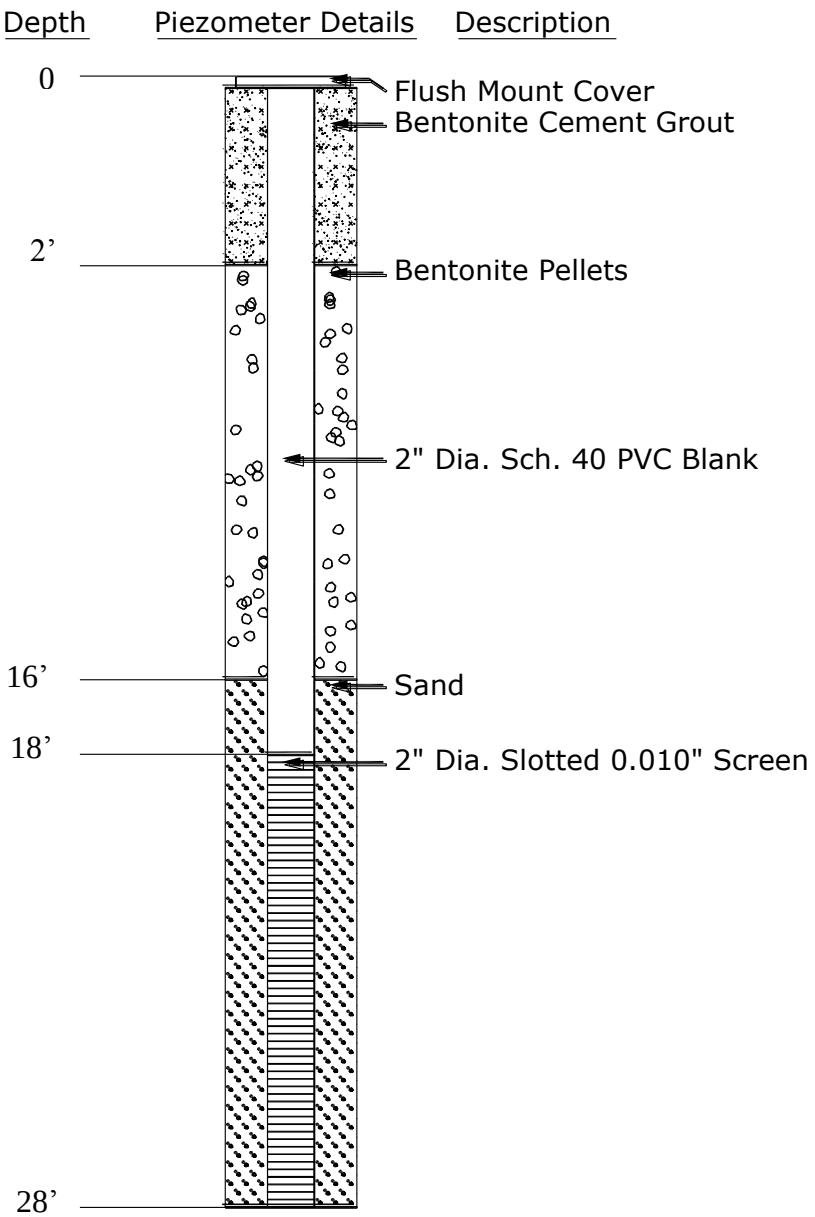
NOTES:

- Piezometer was installed on 7/30/14.
- See Plate 2 for boring location

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

PIEZOMETER INSTALLATION REPORT
PIEZOMETER NO. PZ-2 (B-7)

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE C-2



Water Level Readings

Date	Depth (ft.)	Elev. (ft.)
8/5/14	7.2’	73
8/19/14	7.4	72.8
9/3/14	7.6	72.6

NOTES:

- Piezometer was installed on 8/4/14.
- See Plate 2 for boring location

HVJ ASSOCIATES
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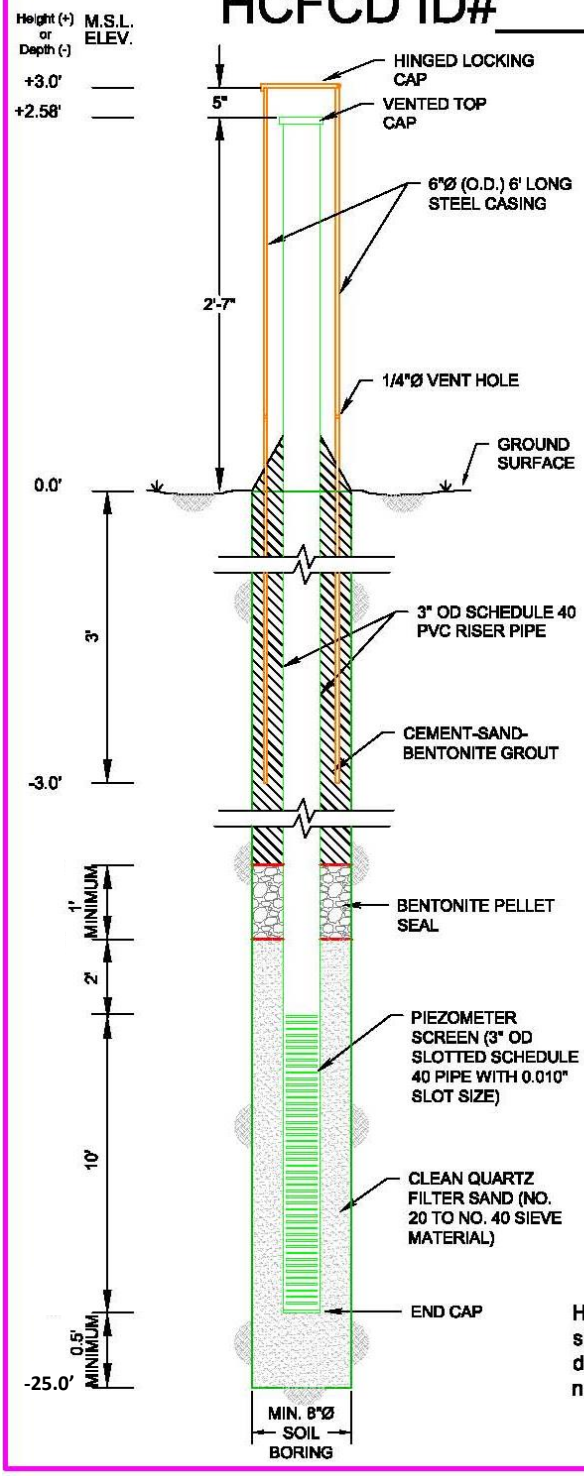
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

PIEZOMETER INSTALLATION REPORT
PIEZOMETER NO. PZ-3 (B-13)

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE C-3

PIEZOMETER INSTALLATION DIAGRAM

HCFCD ID#_____



Installation and Development Details

Piezometer No.:	PZ-4
Location:	DP-2
Installation Date:	8/5/14
Drilling Method:	
Dry Auger	X
Wet Rotary	
Development Date:	8/5/14
Development Method:	Surge Block

Water Level Data	Depth below grade, ft.	Elevation
During Drilling	Dry	
After Installation (24 hrs)	11. 3	63.5'
Before Development	N/A	
After Development (15 days)	13.2	61.6'
Before Development	N/A	
After Development (30 days)	14.6	60.2'

Height above the ground surface is shown as a positive number (+) and depth below ground is shown a negative number (-).

Harris County Flood Control District

Date: January 5, 2007

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 08/18/2014	APPROVED BY: ND	PREPARED BY: SS

PIEZOMETER INSTALLATION REPORT
PIEZOMETER NO. PZ-4 (DP-2)
WBS No. N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE C-4

STATE OF TEXAS WELL REPORT for Tracking #380601

Owner:	**HVJ**	Owner Well #:	**B-4**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 04" N**
Well County:	**Harris**	Longitude:	**095° 21' 23" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date: Started: **7/28/2014**
Completed: **7/28/2014**

Diameter of Hole: Diameter: **4 in From Surface To 28 ft**

Drilling Method: **Mud Rotary**

Borehole Completion: Gravel Packed From: **28 ft to 16 ft**
Gravel Pack Size: **20/40**

Annular Seal Data: 1st Interval: **From 28 ft to 16 ft with 4 sand (#sacks and material)**
2nd Interval: **From 16 ft to 2 ft with 3 chips (#sacks and material)**
3rd Interval: **From 2 ft to 0 ft with 1 cement (#sacks and material)**
Method Used: **No Data**
Cemented By: **No Data**
Distance to Septic Field or other Concentrated Contamination: **No Data**
Distance to Property Line: **No Data**
Method of Verification: **No Data**
Approved by Variance: **No Data**

Surface Completion: **Surface Sleeve Installed**

Water Level: Static level: **22 ft. below land surface on 7/28/2014**
Artesian flow: **No Data**

Packers: **bentonite chips**

Plugging Info: Casing or Cement/Bentonite left in well: **No Data**

Type Of Pump: **No Data**

Well Tests: **No Data**

Water Quality: Type of Water: **No Data**
Depth of Strata: **No Data**
Chemical Analysis Made: **No**
Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's dir supervision) and that each and all of the statements herein are true and correct. The driller

understood that failure to complete the required items will result in the log(s) being returned f completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Driller License Number:	**2963**
Licensed Well Driller Signature:	**Dave Martin**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#380601**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-16', brown, clay
16-28', reddish brown, clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 inch, new, pvc, 28-18, screen, .010
2 inch, new, pvc, 18-0, riser

STATE OF TEXAS WELL REPORT for Tracking #380602

Owner:	**HVJ**	Owner Well #:	**B-7**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 05" N**
Well County:	**Harris**	Longitude:	**095° 20' 42" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date: Started: **7/30/2014**
Completed: **7/30/2014**

Diameter of Hole: Diameter: **4 in From Surface To 28 ft**

Drilling Method: **Mud Rotary**

Borehole Completion: Gravel Packed From: **28 ft to 16 ft**
Gravel Pack Size: **20/40**

Annular Seal Data: 1st Interval: **From 28 ft to 16 ft with 4 sand (#sacks and material)**
2nd Interval: **From 16 ft to 2 ft with 3 chips (#sacks and material)**
3rd Interval: **From 2 ft to 0 ft with 1 cement (#sacks and material)**
Method Used: **No Data**
Cemented By: **No Data**
Distance to Septic Field or other Concentrated Contamination: **No Data**
Distance to Property Line: **No Data**
Method of Verification: **No Data**
Approved by Variance: **No Data**

Surface Completion: **Surface Sleeve Installed**

Water Level: Static level: **No Data**
Artesian flow: **No Data**

Packers: **bentonite chips**

Plugging Info: Casing or Cement/Bentonite left in well: **No Data**

Type Of Pump: **No Data**

Well Tests: **No Data**

Water Quality: Type of Water: **No Data**
Depth of Strata: **No Data**
Chemical Analysis Made: **No**
Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's dir supervision) and that each and all of the statements herein are true and correct. The driller

understood that failure to complete the required items will result in the log(s) being returned f completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Driller License Number:	**2963**
Licensed Well Driller Signature:	**Dave Martin**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

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Please include the report's Tracking number (Tracking **#380602**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
9', brown, clay
9-28', reddish brown, clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 inch, new, pvc, 28-18, screen, .010
2 inch, new, pvc, 18-0, riser

STATE OF TEXAS WELL REPORT for Tracking #380604

Owner:	**HVJ**	Owner Well #:	**B-13**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 05" N**
Well County:	**Harris**	Longitude:	**095° 20' 08" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date: Started: **8/4/2014**
Completed: **8/4/2014**

Diameter of Hole: Diameter: **4 in From Surface To 28 ft**

Drilling Method: **Mud Rotary**

Borehole Completion: Gravel Packed From: **28 ft to 16 ft**
Gravel Pack Size: **20/40**

Annular Seal Data: 1st Interval: **From 28 ft to 16 ft with 4 sand (#sacks and material)**
2nd Interval: **From 16 ft to 2 ft with 3 chips (#sacks and material)**
3rd Interval: **From 2 ft to 0 ft with 1 cement (#sacks and material)**
Method Used: **No Data**
Cemented By: **No Data**
Distance to Septic Field or other Concentrated Contamination: **No Data**
Distance to Property Line: **No Data**
Method of Verification: **No Data**
Approved by Variance: **No Data**

Surface Completion: **Surface Sleeve Installed**

Water Level: Static level: **12 ft. below land surface on 8/4/2014**
Artesian flow: **No Data**

Packers: **bentonite chips**

Plugging Info: Casing or Cement/Bentonite left in well: **No Data**

Type Of Pump: **No Data**

Well Tests: **No Data**

Water Quality: Type of Water: **No Data**
Depth of Strata: **No Data**
Chemical Analysis Made: **No**
Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's dir supervision) and that each and all of the statements herein are true and correct. The driller

understood that failure to complete the required items will result in the log(s) being returned f completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Driller License Number:	**2963**
Licensed Well Driller Signature:	**Dave Martin**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

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Please include the report's Tracking number (Tracking **#380604**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-24', brown and gray, clay
24-28', reddish brown, clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 inch, new, pvc, 28-18, screen, .010
2 inch, new, pvc, 18-0, riser

STATE OF TEXAS WELL REPORT for Tracking #380606

Owner:	**HVJ**	Owner Well #:	**DP-2**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-1**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 54" N**
Well County:	**Harris**	Longitude:	**095° 21' 02" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date: Started: **8/5/2014**
Completed: **8/5/2014**

Diameter of Hole: Diameter: **4 in From Surface To 25 ft**

Drilling Method: **Mud Rotary**

Borehole Completion: Gravel Packed From: **25 ft to 13 ft**
Gravel Pack Size: **20/40**

Annular Seal Data: 1st Interval: **From 25 ft to 15 ft with 2 sand (#sacks and material)**
2nd Interval: **From 13 ft to 2 ft with 2 chips (#sacks and material)**
3rd Interval: **From 2 ft to 0 ft with 1 cement (#sacks and material)**
Method Used: **No Data**
Cemented By: **No Data**
Distance to Septic Field or other Concentrated Contamination: **No Data**
Distance to Property Line: **No Data**
Method of Verification: **No Data**
Approved by Variance: **No Data**

Surface Completion: **No Data**

Water Level: Static level: **No Data**
Artesian flow: **No Data**

Packers: **bentonite chips**

Plugging Info: Casing or Cement/Bentonite left in well: **No Data**

Type Of Pump: **No Data**

Well Tests: **No Data**

Water Quality: Type of Water: **No Data**
Depth of Strata: **No Data**
Chemical Analysis Made: **No**
Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's dir supervision) and that each and all of the statements herein are true and correct. The driller

understood that failure to complete the required items will result in the log(s) being returned f completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Driller License Number:	**2963**
Licensed Well Driller Signature:	**Dave Martin**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#380606**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-17', brown and gray, clay
17-25', reddish brown, clay

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
3 inch, new, pvc, 25-15, screen, .010
3 inch, new, pvc, 15-0, riser

STATE OF TEXAS PLUGGING REPORT for Tracking #97939

Owner:	**HVJ**	Owner Well #:	**B-4**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 04" N**
Well County:	**Harris**	Longitude:	**095° 21' 23" W**
		GPS Brand Used:	**No Data**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Dave Martin**
Driller's License Number of Original Well Driller:	**2963**
Date Well Drilled:	**7/28/2014**
Well Report Tracking Number:	**380601**
Diameter of Borehole:	**4 inch inches**
Total Depth of Borehole:	**28 feet feet**

Date Well Plugged:	**11/7/2014**
Person Actually Performing Plugging Operation:	**Dennis Smith**
License Number of Plugging Operator:	**3102**
Plugging Method:	**Tremmie pipe cement from bottom to top.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **No Data** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 3** 2nd Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 5 lbs bentonite** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data: The plug installer certified that the plug installer plugged this well (or the well was plugge under the plug installer's direct supervision) and that each and all of the statements here are true and correct. The plug installer understood that failure to complete the required

will result in the log(s) being returned for completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Plug Installer License Number:	**3102**
Licensed Plug Installer Signature:	**Dennis Ray Smith**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#97939**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

STATE OF TEXAS PLUGGING REPORT for Tracking #97940

Owner:	**HVJ**	Owner Well #:	**B-7**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 05" N**
Well County:	**Harris**	Longitude:	**095° 20' 42" W**
		GPS Brand Used:	**No Data**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Dave Martin**
Driller's License Number of Original Well Driller:	**2963**
Date Well Drilled:	**7/30/2014**
Well Report Tracking Number:	**380602**
Diameter of Borehole:	**4 inch inches**
Total Depth of Borehole:	**28 feet feet**

Date Well Plugged:	**11/7/2014**
Person Actually Performing Plugging Operation:	**Dennis Smith**
License Number of Plugging Operator:	**3102**
Plugging Method:	**Tremmie pipe cement from bottom to top.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **No Data** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 3** 2nd Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 5 lbs bentonite** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data: The plug installer certified that the plug installer plugged this well (or the well was plugge under the plug installer's direct supervision) and that each and all of the statements here are true and correct. The plug installer understood that failure to complete the required

will result in the log(s) being returned for completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Plug Installer License Number:	**3102**
Licensed Plug Installer Signature:	**Dennis Ray Smith**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#97940**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

STATE OF TEXAS PLUGGING REPORT for Tracking #97941

Owner:	**HVJ**	Owner Well #:	**B-13**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-4**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 05" N**
Well County:	**Harris**	Longitude:	**095° 20' 08" W**
		GPS Brand Used:	**No Data**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Dave Martin**
Driller's License Number of Original Well Driller:	**2963**
Date Well Drilled:	**8/4/2014**
Well Report Tracking Number:	**380604**
Diameter of Borehole:	**4 inch inches**
Total Depth of Borehole:	**28 feet feet**

Date Well Plugged:	**11/7/2014**
Person Actually Performing Plugging Operation:	**Dennis Smith**
License Number of Plugging Operator:	**3102**
Plugging Method:	**Tremmie pipe cement from bottom to top.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **2 inches diameter, From 4 ft to 24 ft** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 3** 2nd Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 5 lbs bentonite** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data: The plug installer certified that the plug installer plugged this well (or the well was plugge under the plug installer's direct supervision) and that each and all of the statements here are true and correct. The plug installer understood that failure to complete the required

will result in the log(s) being returned for completion and resubmittal.

Company Information:	**Professional Service Industries** **3730 Dacoma Street** **Houston , TX 77092**
Plug Installer License Number:	**3102**
Licensed Plug Installer Signature:	**Dennis Ray Smith**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#97941**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

STATE OF TEXAS PLUGGING REPORT for Tracking #97942

Owner:	**HVJ**	Owner Well #:	**DP -2**
Address:	**6120 S. Dairy Ashford Houston , TX 77076**	Grid #:	**65-06-1**
Well Location:	**Greens Road Houston , TX**	Latitude:	**29° 57' 54" N**
Well County:	**Harris**	Longitude:	**095° 21' 02" W**
		GPS Brand Used:	**No Data**
Well Type:	**Monitor**		

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Dave Martin**
Driller's License Number of Original Well Driller:	**2963**
Date Well Drilled:	**8/5/2014**
Well Report Tracking Number:	**380606**
Diameter of Borehole:	**4 inch inches**
Total Depth of Borehole:	**28 feet feet**

Date Well Plugged:	**11/7/2014**
Person Actually Performing Plugging Operation:	**Dennis Smith**
License Number of Plugging Operator:	**3102**
Plugging Method:	**Tremmie pipe cement from bottom to top.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **3 inches diameter, From 0 ft to 20 ft** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 3** 2nd Interval: **From 0 ft to 28 ft; Sack(s)/type of cement used: 5 lbs bentonite** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugg under the plug installer's direct supervision) and that each and all of the statements he are true and correct. The plug installer understood that failure to complete the required will result in the log(s) being returned for completion and resubmittal.
Company Information:	

	Professional Service Industries **3730 Dacoma Street** **Houston , TX 77092**
Plug Installer License Number:	**3102**
Licensed Plug Installer Signature:	**Dennis Ray Smith**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#97942**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
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(512) 463-7880

APPENDIX D

CRUMB TEST RESULTS

HVJ Associates
Crumb Test (ASTM D6572)

Project name: Greens Road from Aldine Westfield to JFK **Project No.:** HG0519680

Boring	Sample no.	Sample depth (ft.)	Trial no.	10 min.	30 min.
DP-1	light grey, brownish yellow sandy clay with calcareous deposits	8-10	1	1	1
			2	1	1
			3	1	1
DP-2	light grey silty clay with calcareous deposits	6-8	1	1	1
			2	1	1
			3	1	1
DP-2	reddish brown, light grey silty clay	16-18	1	1	1
			2	2	2
			3	1	1
DP-3	brown, grey silty sand; silty clay	4-6	1	1	1
			2	1	1
			3	1	1

1 = non-dispersive
2 = barely dispersive
3 = dispersive
4 = very dispersive

APPENDIX E

PINHOLE TEST RESULTS

HVJ Associates, Inc.

PINHOLE TEST ASTM D-4647

Test Method Used : Method A

Sample Description	Gray Sandy Clay	**Date:**	8/18/2014
Compaction characteristics	Good	**Boring No.:**	DP-1
Water content	18%	**Sample No.:**	S-1
Distilled water added:	Yes	**Sample Depth:**	4'-6'
Curing time	None		
Project name:	Greens Road from Aldine Westfield to JFK		
Final hole size	1.0 mm		

PINHOLE TEST DATA

Clock Time	Head (in.)	Flow		Flow Rate ml/sec	Turbidity from Side						Barely clear from top	Remarks
		ml.	sec.		Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Clear		
16:20:00	2	150	300	0.50						X		
16:25:00	2	300	600	0.50						X		
16:35:00	2	300	600	0.50						X		
16:40:00	2	150	300	0.50						X		
16:45:00	7	250	300	0.83						X		
16:50:00	15	375	300	1.25						X		
16:55:00	40	550	300	1.83						X		
17:00:00	40	550	300	1.83						X		
												Classification = ND1

Note :

D1,D2 : Dispersive

ND4, ND3 : Slightly to Moderately Dispersive

ND2, ND1 : Nondispersive

PLATE E-1

HVJ Associates, Inc.

PINHOLE TEST ASTM D-4647

Test Method Used : Method A

Sample Description	Gray Clay	**Date:**	8/18/2014
Compaction characteristics	Good	**Boring No.:**	DP-3
Water content	18%	**Sample No.:**	S-2
Distilled water added:	Yes	**Sample Depth:**	6'-8'
Curing time	None		
Project name:	Greens Road from Aldine Westfield to JFK		
Final hole size	1.0 mm		

PINHOLE TEST DATA

Clock Time	Head (in.)	Flow		Flow Rate ml/sec	Turbidity from Side						Barely clear from top	Remarks
		ml.	sec.		Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Clear		
16:20:00	2	125	300	0.42						X		
16:25:00	2	250	600	0.42						X		
16:35:00	2	250	600	0.42						X		
16:40:00	2	125	300	0.42						X		
16:45:00	7	200	300	0.67						X		
16:50:00	15	300	300	1.00						X		
16:55:00	40	400	300	1.33						X		
17:00:00	40	400	300	1.33						X		
												Classification = ND1

Note :

D1,D2 : Dispersive

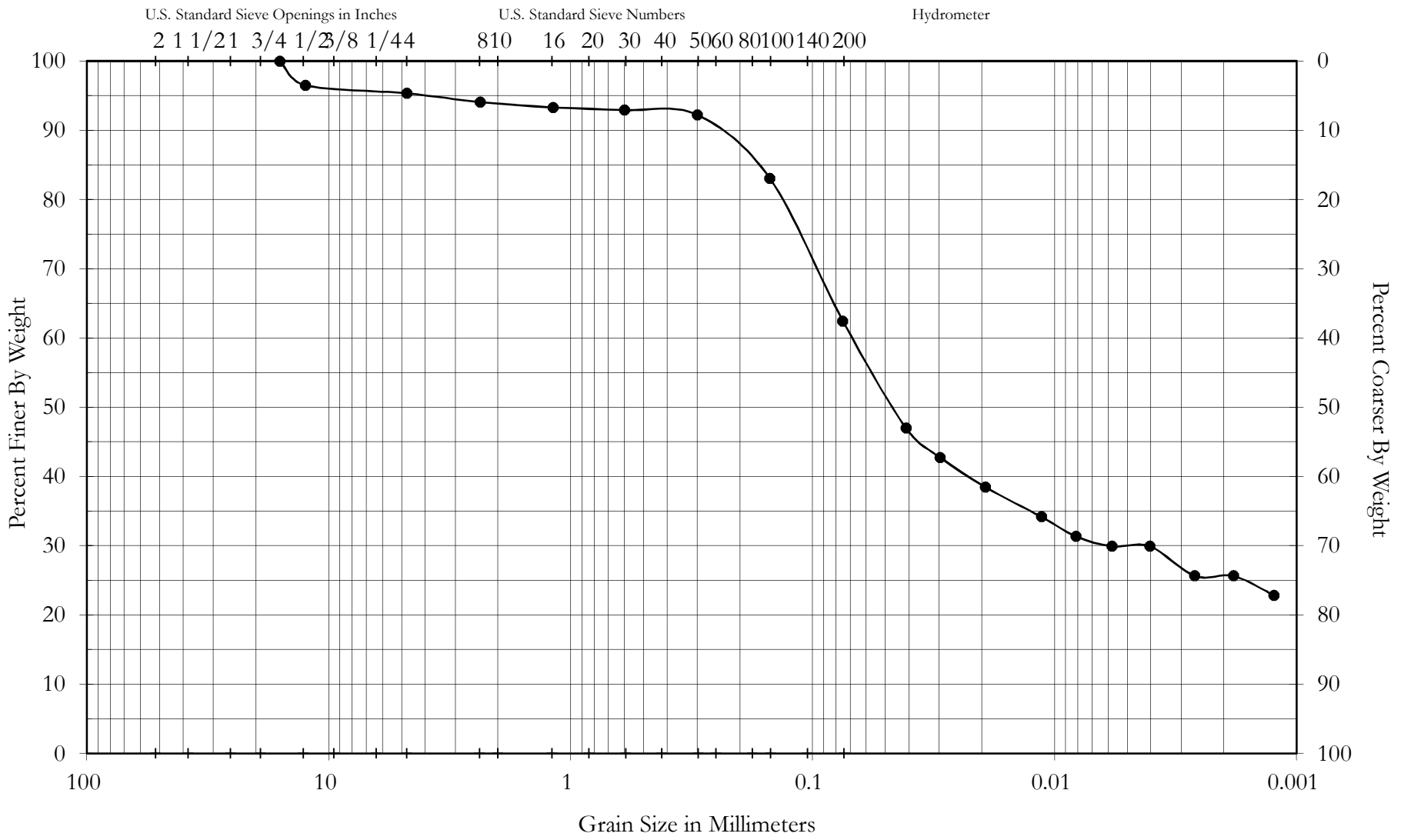
ND4, ND3 : Slightly to Moderately Dispersive

ND2, ND1 : Nondispersive

PLATE E-2

APPENDIX F

SIEVE ANALYSIS AND HYDROMETER TEST RESULTS



Sample Location

Hoods Bayou
Slope
(Depth = 15 feet)

D_{50} = 0.047 mm

Classification

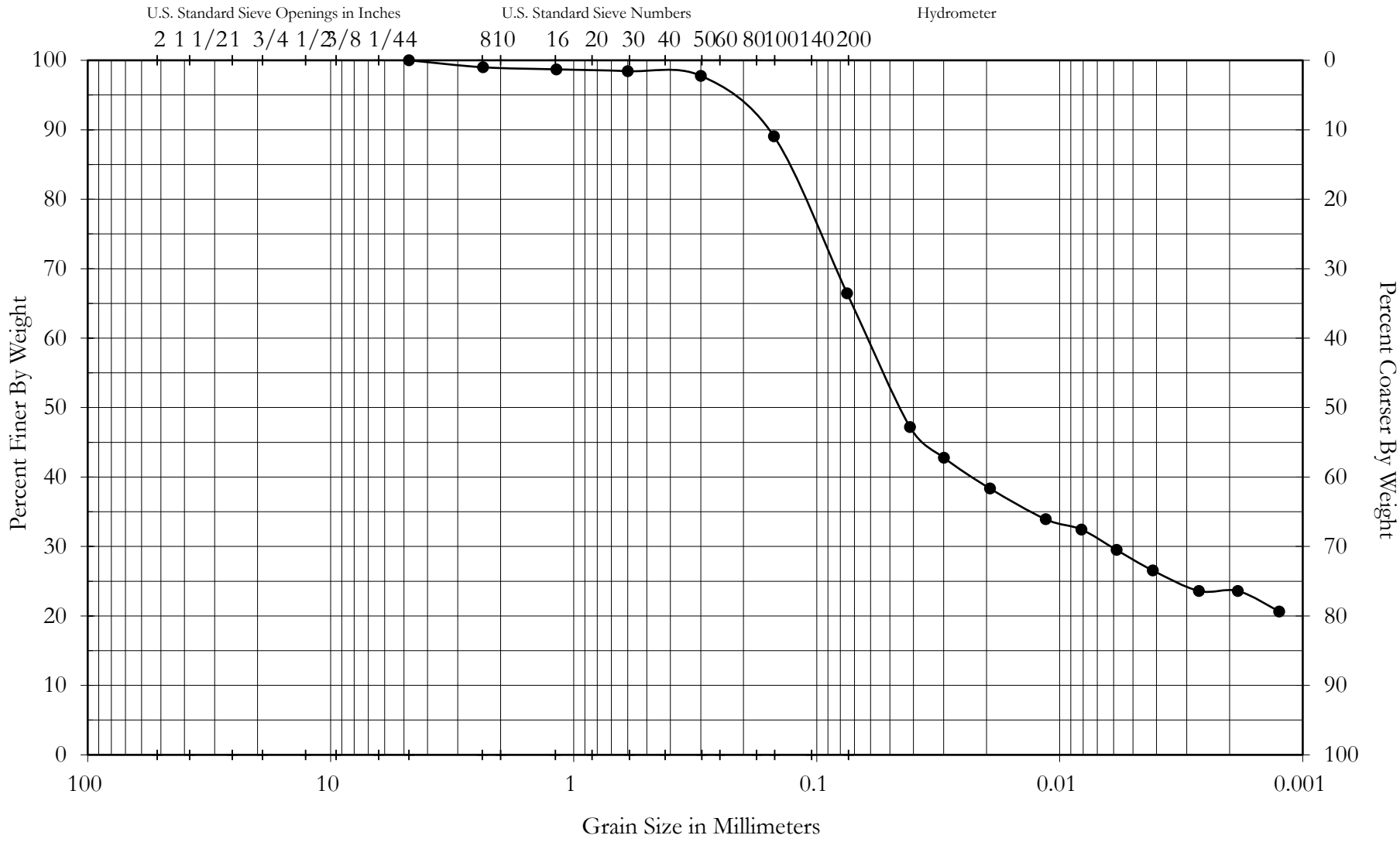
Reddish Gray
Sandy Lean Clay

HVJ ASSOCIATES, INC.

GRAIN SIZE ANALYSIS CURVE
ASTM D6913

PROJECT NO:
HG0519680

PLATE F-1



Sample Location

Hoods Bayou
Bottom
(Depth = 25 feet)

D_{50} = 0.045 mm

Classification

Reddish Gray
Sandy Lean Clay

HVJ ASSOCIATES, INC.

GRAIN SIZE ANALYSIS CURVE
ASTM D6913

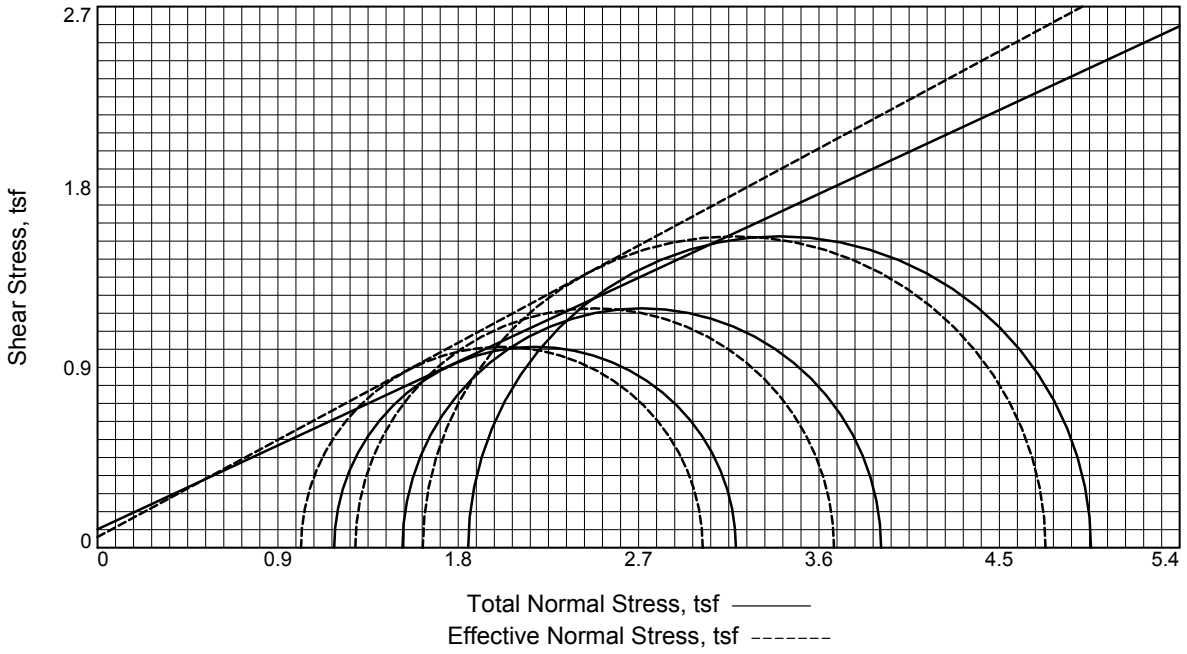
PROJECT NO:
HG0519680

PLATE F-2

APPENDIX G

CONSOLIDATED UNDRAINED TEST RESULTS

TRIAXIAL SHEAR TEST REPORT



Type of Test: CU with Pore Pressures **Sample Type:** undisturbed

No.	Fluid Press. tsf		Fail. Stress, tsf		Ult. Stress, tsf		Principal Stresses at Failure tsf	
	Cell	Back	Deviator	Total Pore Pressure	Deviator	Total Pore Pressure	$\overline{\sigma}_1$	$\overline{\sigma}_3$
1	4.061	2.880	2.005	3.046			3.020	1.015
2	4.401	2.880	2.389	3.115			3.675	1.286
3	4.730	2.880	3.108	3.107			4.731	1.623

No.	Consolidated Sample Parameters						
	% Water Content	Dry Dens. pcf	Satur-ation	Void Ratio	Diameter in.	Height in.	Strain Rate in/min.
1	20.6	109.5	100.0%	0.5673	2.74	5.53	0.01
2	20.8	109.2	100.0%	0.5719	2.67	5.46	0.02
3	21.2	108.5	100.0%	0.5830	2.71	5.51	0.01

Mohr-Coulomb Strength Parameters	Total	Effective
Strength intercept, c=	0.092 tsf	0.053 tsf
Friction angle, ϕ =	24.9 deg	28.3 deg
Tangent, ϕ =	0.46	0.54

Material Description

Medium Plasticity Lean clay with sand

LL= 33 **PL=** 23 **PI=** 10

Client:

Project: Greens Road

Source of Sample: DP-1 **Depth:** 10-12

Sample Number: 6

Date Sampled: 8/9/2014

File: HG-05-2

Remarks:

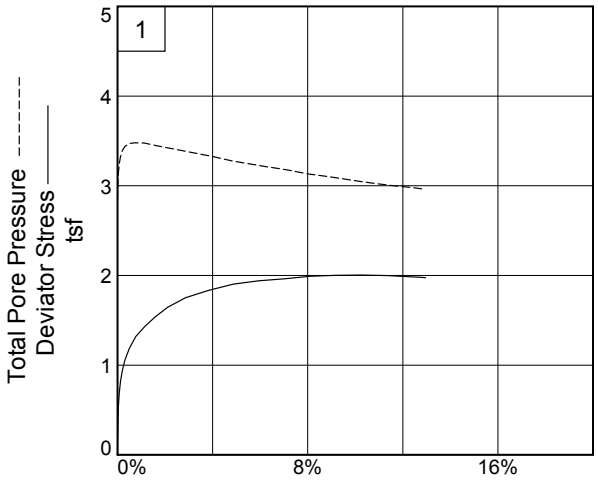
% Passing #200 sieve = 84.5

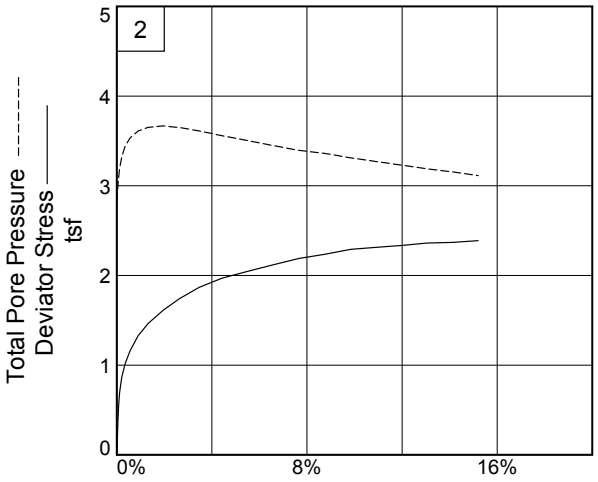
sheared at 1% axial strain per hour at engineer's request

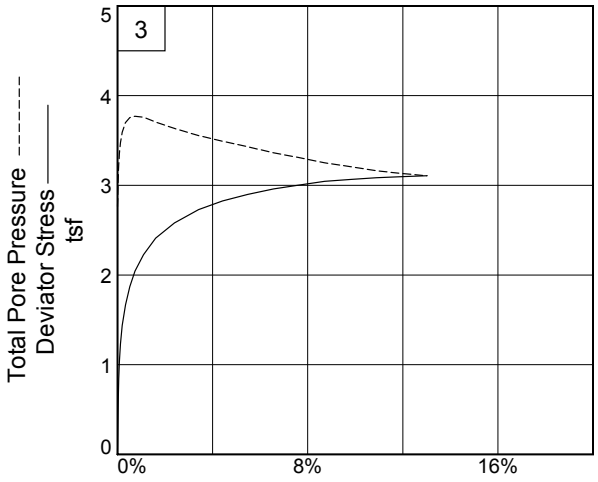
HVJ ASSOCIATES
6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010

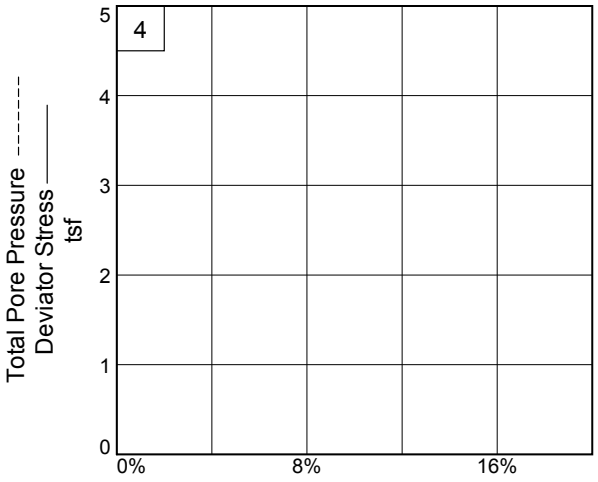
Proj. No.: HG-05-19680

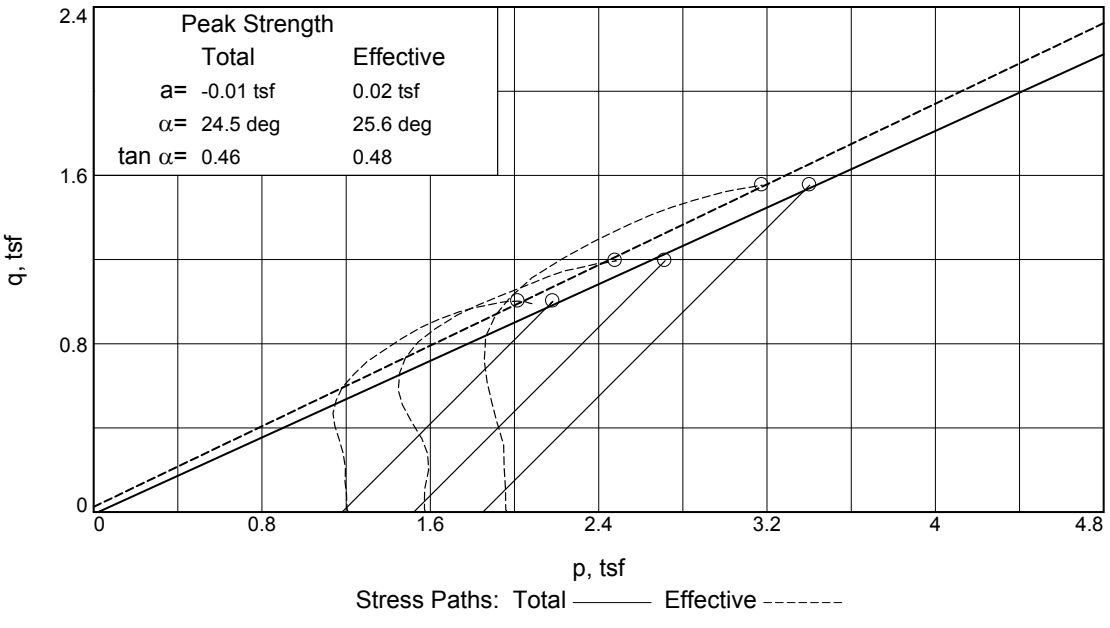
Figure _____











Client:

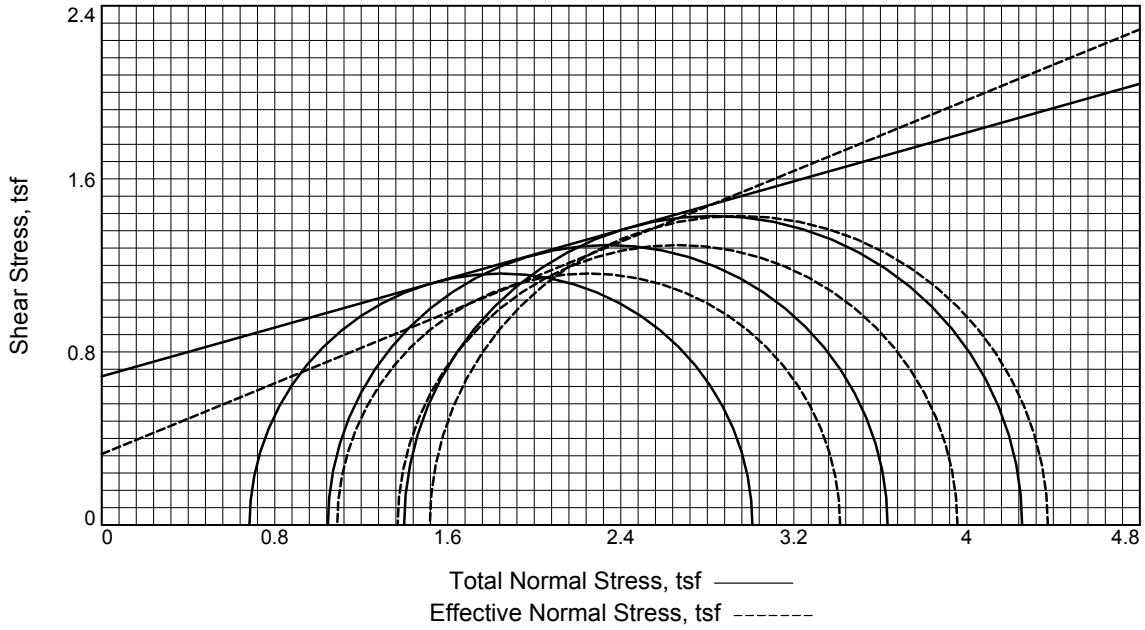
Project: Greens Road

Source of Sample: DP-1 **Depth:** 10-12 **Sample Number:** 6

Project No.: HG-05-19680 **Figure** _____

HVJ ASSOCIATES, INC.

TRIAXIAL SHEAR TEST REPORT



Type of Test: CU with Pore Pressures **Sample Type:** undisturbed

No.	Fluid Press. tsf		Fail. Stress, tsf		Ult. Stress, tsf		Principal Stresses at Failure tsf	
	Cell	Back	Deviator	Total Pore Pressure	Deviator	Total Pore Pressure	$\overline{\sigma}_1$	$\overline{\sigma}_3$
1	3.563	2.880	2.325	2.475			3.414	1.089
2	3.925	2.880	2.588	2.557			3.956	1.368
3	4.278	2.880	2.857	2.761			4.374	1.517

No.	Consolidated Sample Parameters						
	% Water Content	Dry Dens. pcf	Satur-ation	Void Ratio	Diameter in.	Height in.	Strain Rate in/min.
1	17.7	115.6	100.0%	0.4855	2.74	5.51	0.01
2	17.4	116.2	100.0%	0.4780	2.72	5.53	0.01
3	15.5	120.3	100.0%	0.4274	2.76	5.53	0.02

Mohr-Coulomb Strength Parameters	Total	Effective
Strength intercept, c=	0.687 tsf	0.328 tsf
Friction angle, ϕ =	15.7 deg	22.2 deg
Tangent, ϕ =	0.28	0.41

Material Description

High Plasticity lean clay

LL= 44 **PL=** 16 **PI=** 28

Client:

Project: Greens Road

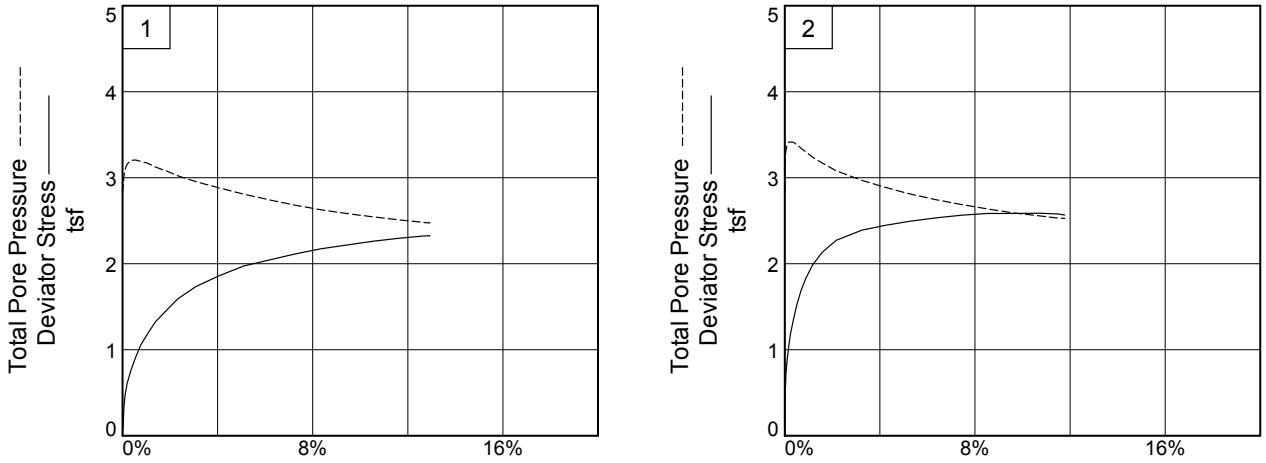
Source of Sample: DP-3 **Depth:** 18-20
Sample Number: 10

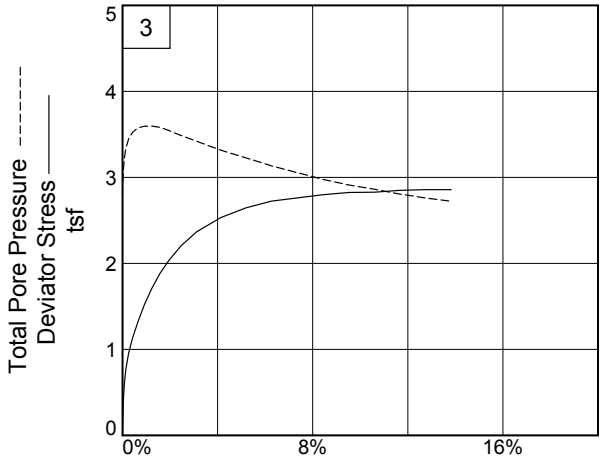
HVJ ASSOCIATES 6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010

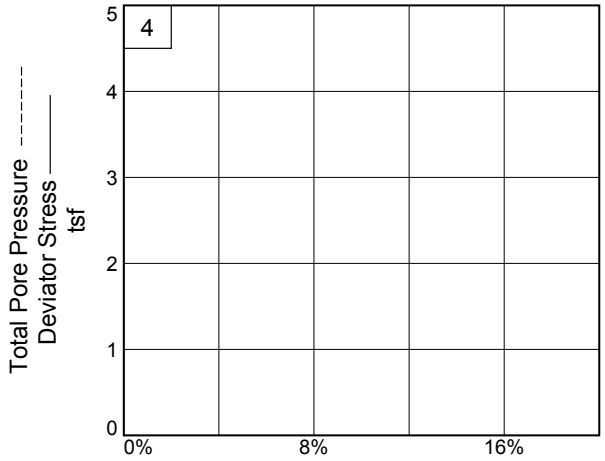
Date Sampled: 8/8/2014
File: HG-05-2
Remarks:
% Passing #200 sieve = 90.7
shear tested at 1% per hour by engineer's instruction

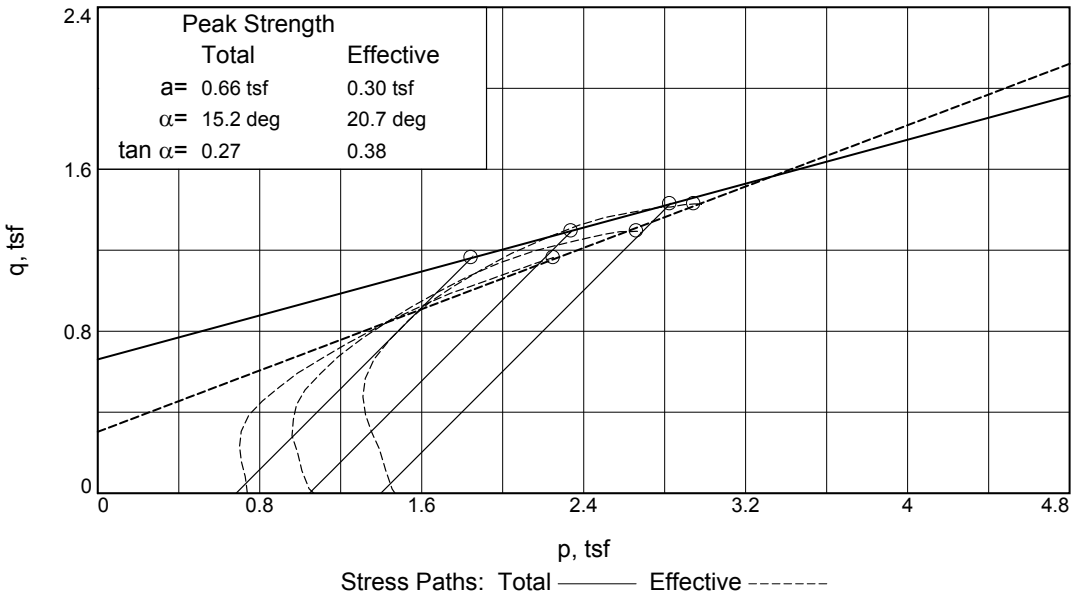
Proj. No.: HG-05-19680
Figure _____

Tested By: KC









Client:

Project: Greens Road

Source of Sample: DP-3 **Depth:** 18-20 **Sample Number:** 10

Project No.: HG-05-19680 **Figure** _____

HVJ ASSOCIATES, INC.

Tested By: KC

APPENDIX H

DRILLED SHAFT FOUNDATION DESIGN DATA

SOIL STRENGTH ANALYSIS

WinCore
Version 3.1

County	Harris	Hole	BR-1	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/5/2014
Control	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
		Offset	19.16 LT	GW Elev.	N/A

TAT Values Preferentially Used **Soil reduction factor of 0.7 applied**

Strata No.	Elev. (Feet) From	To	TCP Unit Friction	TAT Cohesion (PSF)	TAT Phi Degrees	TAT Unit Friction (TSF)	Accumulative Friction (T/F)
1	77.2	76.1	0.00	0	0.0	0.00	0.00
2	76.1	66.7	0.16	0	0.0	0.16	1.55
3	66.7	60.2	0.33	1426	0.0	0.25	3.17
4	60.2	51.7	0.46	4133	0.0	0.72	9.32
5	51.7	41.7	0.68	2570	0.0	0.45	13.82
6	41.7	26.7	0.47	0	0.0	0.47	20.82
7	26.7	21.7	0.48	1375	0.0	0.24	22.02
8	21.7	11.7	0.54	0	0.0	0.54	27.45
9	11.7	-3.3	0.39	4414	0.0	0.77	39.42

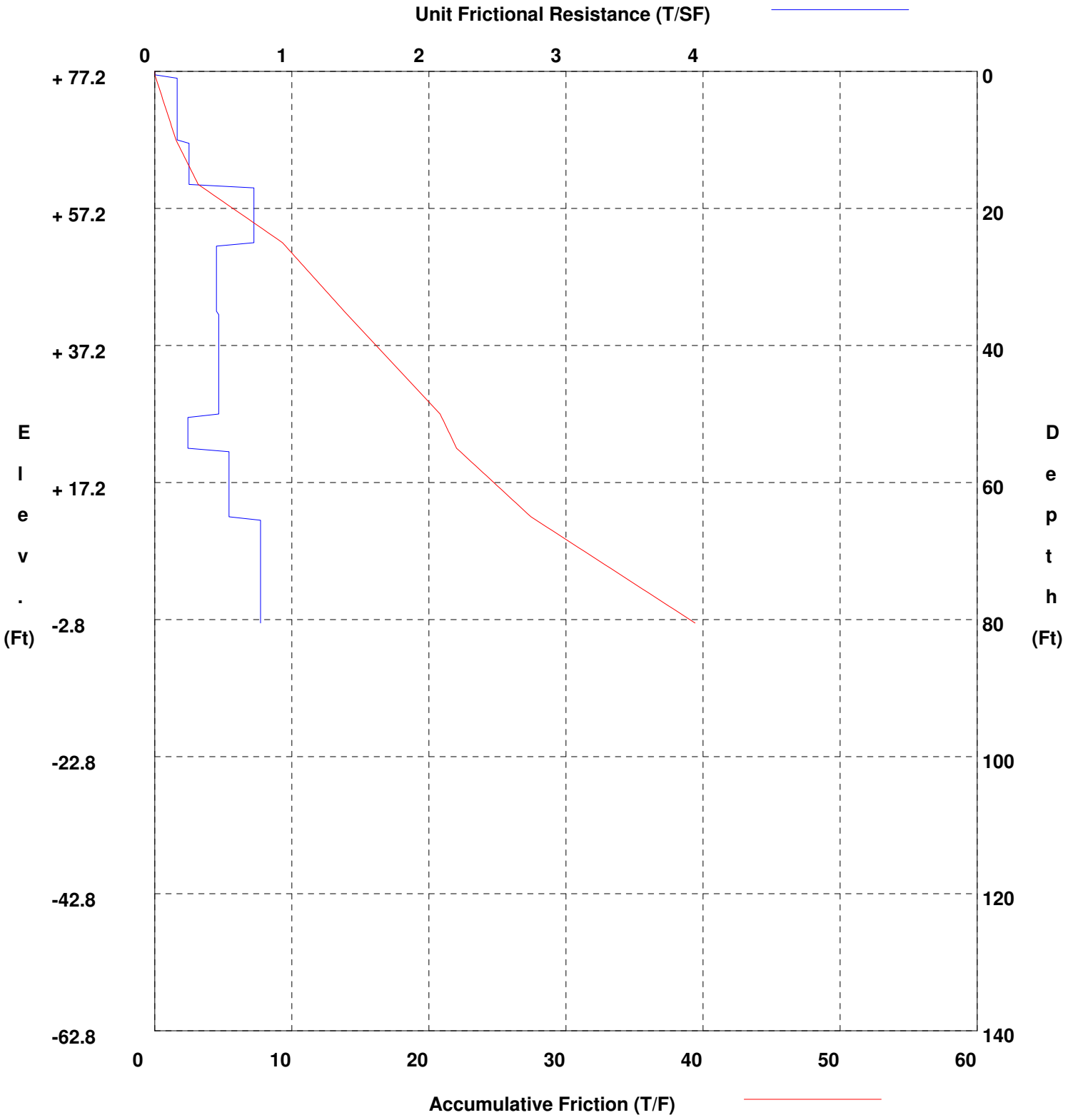
SKIN FRICTION DESIGN

WinCore
Version 3.1

County	Harris	Hole	BR-1	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/5/2014
Control	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
		Offset	19.16 LT	GW Elev.	N/A

Drilled Shaft Design: Soil Reduction Factor = 0.7

TAT Friction Values Used



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SOIL STRENGTH ANALYSIS

WinCore
Version 3.1

County	Harris	Hole	BR-2	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Control	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
		Offset	2.43 LT	GW Elev.	N/A

TAT Values Preferentially Used

Soil reduction factor of 0.7 applied

Strata No.	Elev. (Feet) From	To	TCP Unit Friction	TAT Cohesion (PSF)	TAT Phi Degrees	TAT Unit Friction (TSF)	Accumulative Friction (T/F)
1	76.7	75.6	0.00	0	0.0	0.00	0.00
2	75.6	61.2	0.26	2894	0.0	0.51	7.34
3	61.2	36.2	0.37	1660	0.0	0.29	14.61
4	36.2	26.2	0.30	2398	0.0	0.42	18.80
5	26.2	-3.8	0.61	3989	0.0	0.70	40.09

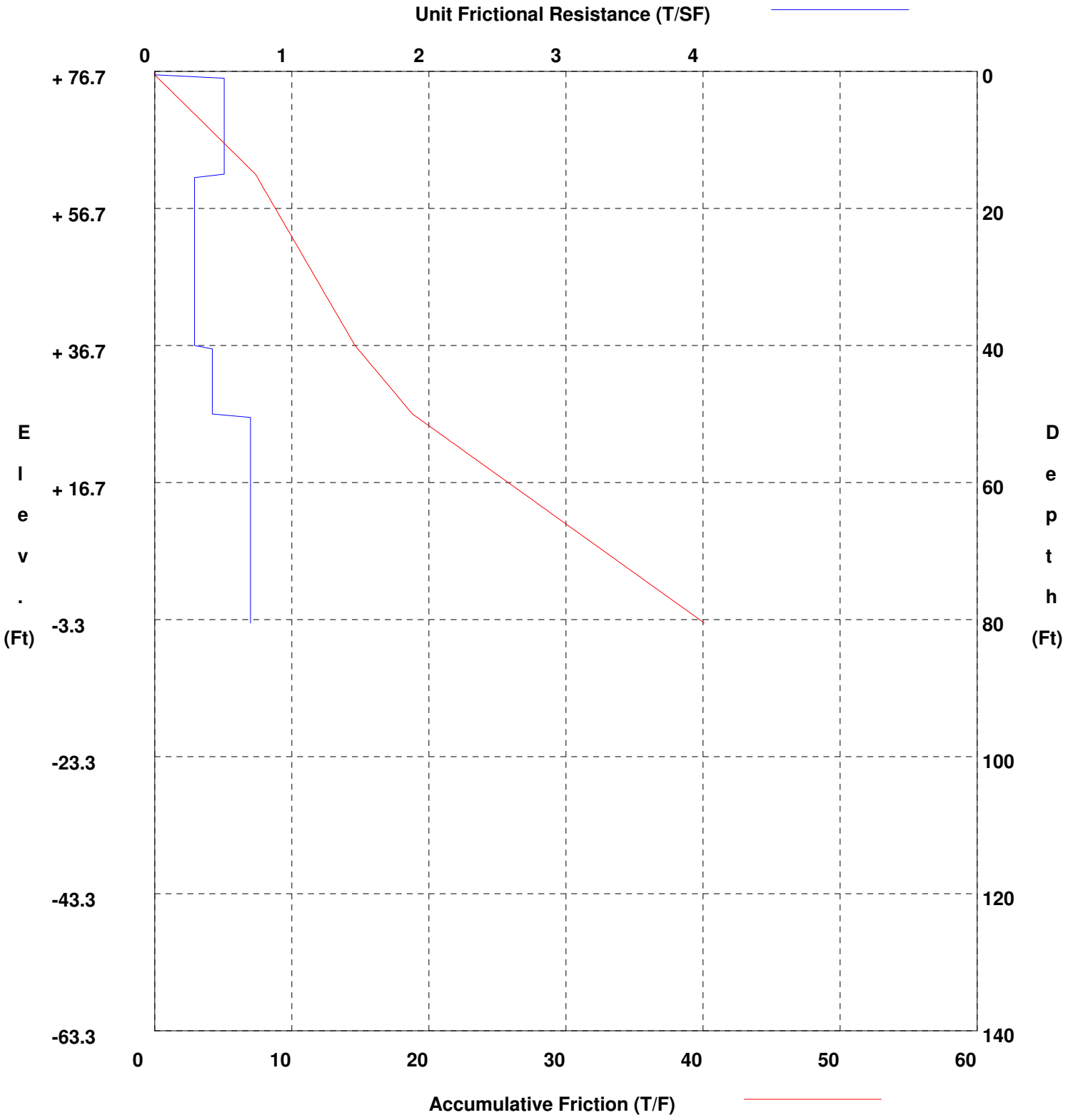
SKIN FRICTION DESIGN

WinCore
Version 3.1

County	Harris	Hole	BR-2	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Control	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
		Offset	2.43 LT	GW Elev.	N/A

Drilled Shaft Design: Soil Reduction Factor = 0.7

TAT Friction Values Used



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APPENDIX I

ALLOWABLE DRIVEN PILE SKIN FRICTION

SOIL STRENGTH ANALYSIS

WinCore
Version 3.1

County	Harris	Hole	BR-1	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/5/2014
Control	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
		Offset	19.16 LT	GW Elev.	N/A

TAT Values Preferentially Used **Skin Friction Limit = 1.25 tsf** **No soil reduction factor applied**

Strata No.	Elev. (Feet) From	To	TCP Unit Friction	TAT Cohesion (PSF)	TAT Phi Degrees	TAT Unit Friction (TSF)	Accumulative Friction (T/F)
1	77.2	76.1	0.00	0	0.0	0.00	0.00
2	76.1	66.7	0.23	0	0.0	0.23	2.22
3	66.7	60.2	0.47	1426	0.0	0.36	4.53
4	60.2	51.7	0.65	4133	0.0	1.03	13.32
5	51.7	41.7	0.97	2570	0.0	0.64	19.74
6	41.7	26.7	0.67	0	0.0	0.67	29.74
7	26.7	21.7	0.68	1375	0.0	0.34	31.46
8	21.7	11.7	0.78	0	0.0	0.78	39.21
9	11.7	-3.3	0.56	4414	0.0	1.10	56.31

SKIN FRICTION DESIGN

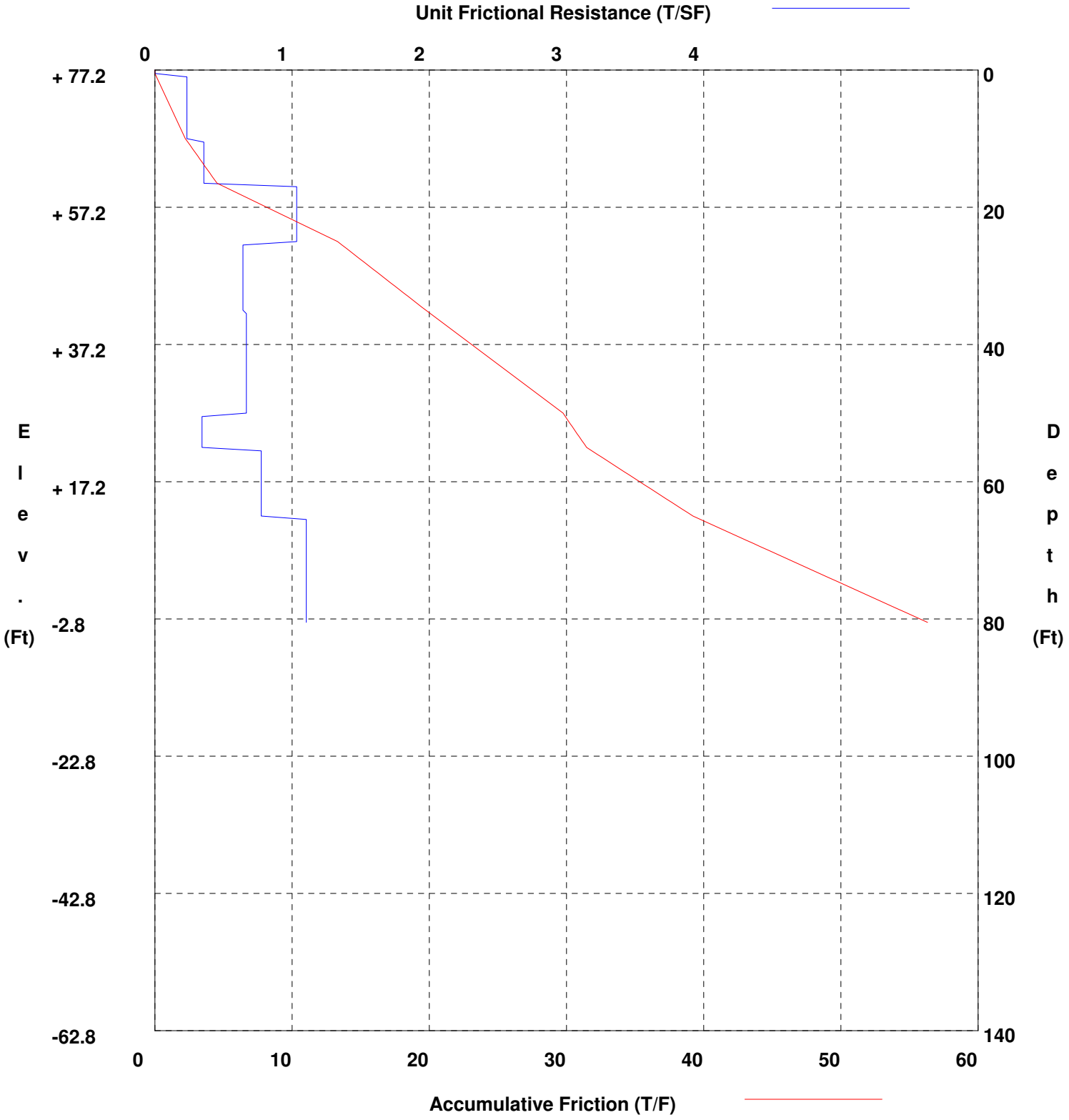
WinCore
Version 3.1

County	Harris	Hole	BR-1	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/5/2014
Control	0912-71-739	Station	37+65.83	Grnd. Elev.	77.17 ft
		Offset	19.16 LT	GW Elev.	N/A

Piling Design: No Soil Reduction Factor

TAT Friction Values Used

Skin Friction Limit = 1.3 tsf



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SOIL STRENGTH ANALYSIS

WinCore
Version 3.1

County	Harris	Hole	BR-2	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Control	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
		Offset	2.43 LT	GW Elev.	N/A

TAT Values Preferentially Used **Skin Friction Limit = 1.25 tsf** **No soil reduction factor applied**

Strata No.	Elev. (Feet) From	To	TCP Unit Friction	TAT Cohesion (PSF)	TAT Phi Degrees	TAT Unit Friction (TSF)	Accumulative Friction (T/F)
1	76.7	75.6	0.00	0	0.0	0.00	0.00
2	75.6	61.2	0.38	2894	0.0	0.72	10.49
3	61.2	36.2	0.53	1660	0.0	0.41	20.86
4	36.2	26.2	0.43	2398	0.0	0.60	26.86
5	26.2	-3.8	0.88	3989	0.0	1.00	57.27

SKIN FRICTION DESIGN

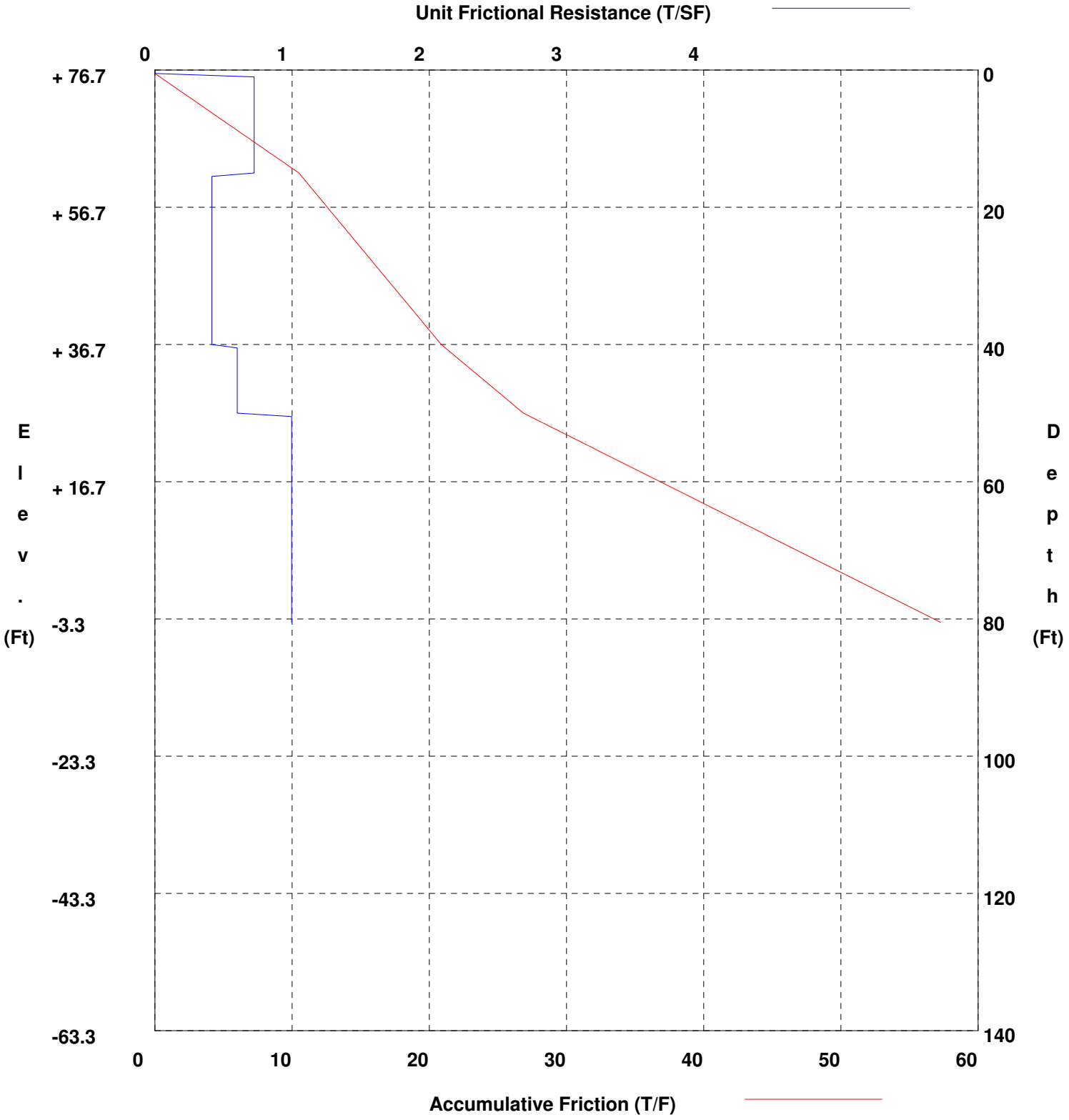
WinCore
Version 3.1

County	Harris	Hole	BR-2	District	Houston
Highway	Greens Road	Structure	Bridge	Date	8/6/2014
Control	0912-71-739	Station	36+39.50	Grnd. Elev.	76.73 ft
		Offset	2.43 LT	GW Elev.	N/A

Piling Design: No Soil Reduction Factor

TAT Friction Values Used

Skin Friction Limit = 1.3 tsf



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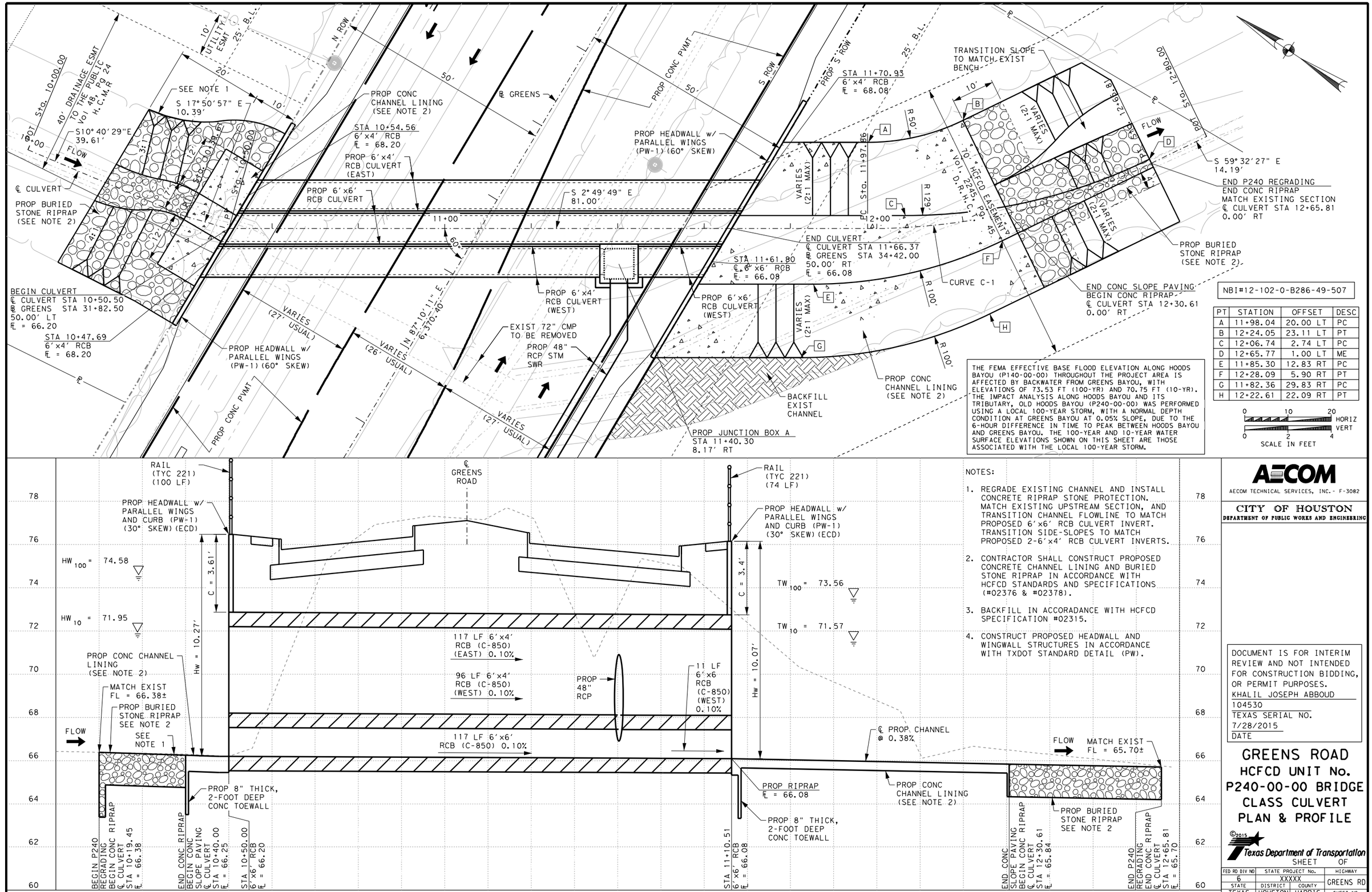
APPENDIX J

LPILE PARAMETER TABLE

Boring No.	Groundwater Depth, Feet	LPILE Parameters							
		Depth, Feet	Soil Type	Effective Unit Weight (pci)	Cohesion, psi	ϕ, deg	Modulus of Subgrade Reaction K, pci		ε_{50}
							Static	Cyclic	
BR-1	23.6	0.0 - 23.6	Stiff clay without free water	0.076	9.7		500 pci	200 pci	0.007
		23.6-35.5	Very stiff clay without free water	0.037	18.1		1000 pci	400 pci	0.005
		35.5-50.5	Dense sand (Reese)	0.033		34	60 pci		
		50.5-55.5	Stiff clay without free water	0.033	9.7		500 pci	200 pci	0.007
		55.5-65.5	Very Dense sand (Reese)	0.033		36	60 pci		
		65.5-80.0	Hard clay without free water	0.040	33.3		2000 pci	800 pci	0.004
BR-2	20.6	0.0-15.5	Very stiff clay without free water	0.079	27.8		1000 pci	400 pci	0.005
		15.5-20.6	Very stiff clay without free water	0.075	16.7		1000 pci	400 pci	0.005
		20.6-40.5	Soft clay without free water	0.037	6.9		100 pci	---	0.01
		40.5-50.5	Very stiff clay without free water	0.034	16.7		1000 pci	400 pci	0.005
		50.5-80.0	Very stiff clay without free water	0.036	23.6		1000 pci	400 pci	0.005

APPENDIX K

PROPOSED CULVERT PLAN AND PROFILE



PT	STATION	OFFSET	DESC
A	11+98.04	20.00 LT	PC
B	12+24.05	23.11 LT	PT
C	12+06.74	2.74 LT	PC
D	12+65.77	1.00 LT	ME
E	11+85.30	12.83 RT	PC
F	12+28.09	5.90 RT	PT
G	11+82.36	29.83 RT	PC
H	12+22.61	22.09 RT	PT

NOTES:

1. REGRADE EXISTING CHANNEL AND INSTALL CONCRETE RIPRAP STONE PROTECTION. MATCH EXISTING UPSTREAM SECTION, AND TRANSITION CHANNEL FLOWLINE TO MATCH PROPOSED 6'x6' RCB CULVERT INVERT. TRANSITION SIDE-SLOPES TO MATCH PROPOSED 2-6'x4' RCB CULVERT INVERTS.
2. CONTRACTOR SHALL CONSTRUCT PROPOSED CONCRETE CHANNEL LINING AND BURIED STONE RIPRAP IN ACCORDANCE WITH HCFCD STANDARDS AND SPECIFICATIONS (#02376 & #02378).
3. BACKFILL IN ACCORADANCE WITH HCFCD SPECIFICATION #02315.
4. CONSTRUCT PROPOSED HEADWALL AND WINGWALL STRUCTURES IN ACCORDANCE WITH TXDOT STANDARD DETAIL (PW).

AECOM
AECOM TECHNICAL SERVICES, INC.- F-3082

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

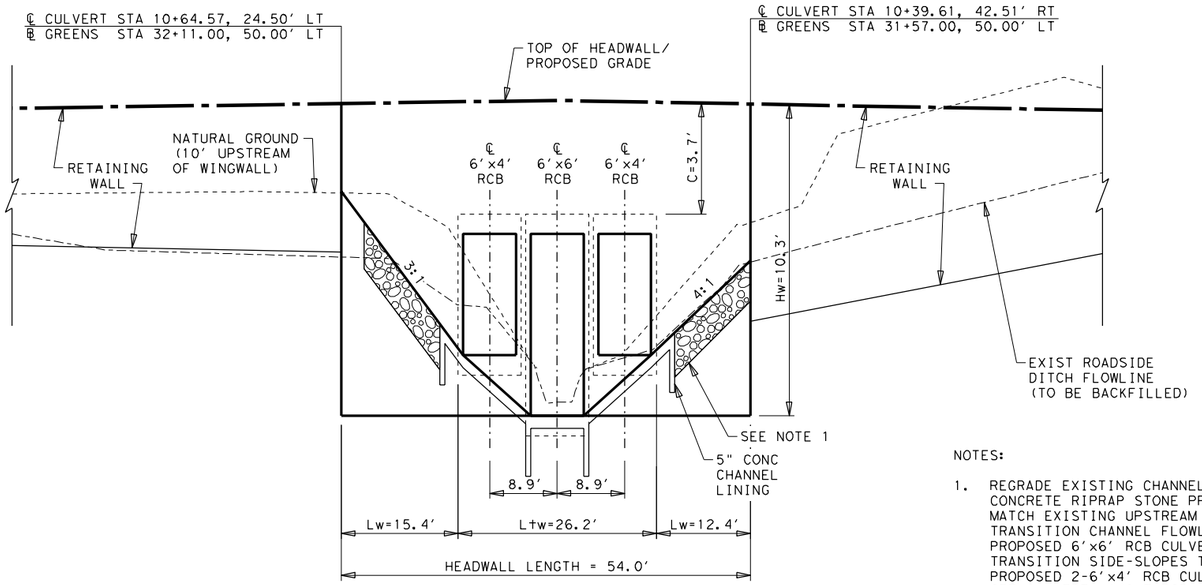
DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
KHALIL JOSEPH ABBOUD
104530
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD HCFCD UNIT No. P240-00-00 BRIDGE CLASS CULVERT PLAN & PROFILE

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

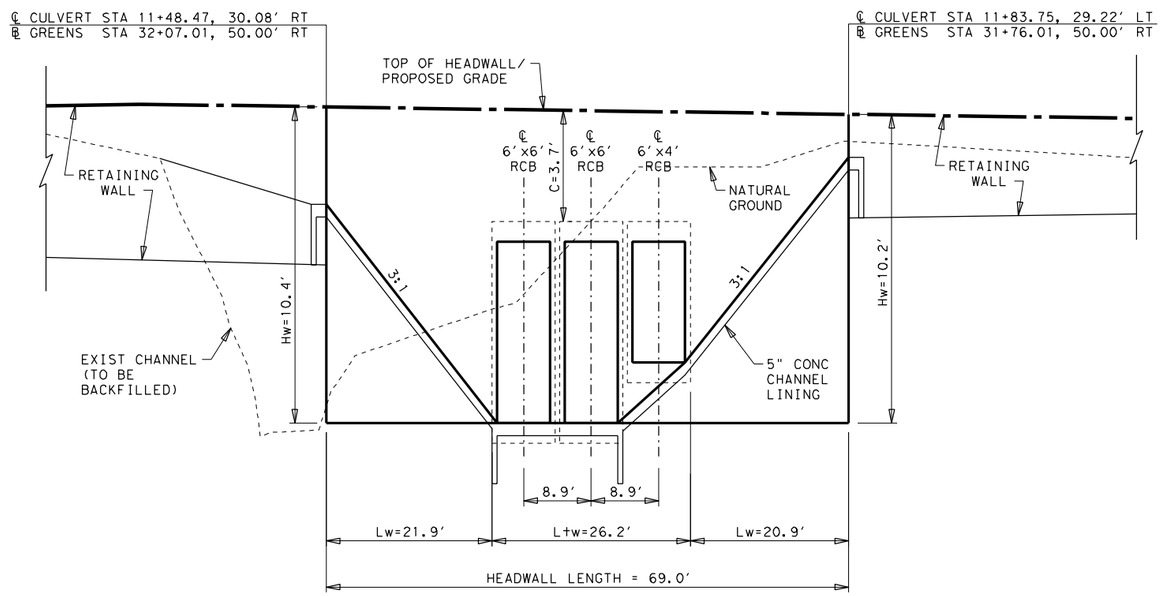
7/28/2015
4:57:19 PM
P:*PWD\City of Houston\60178890 - GreensRD-West\900 Cadd\Sheet\CULVERT*LAYOUT.dgn



UPSTREAM HEADWALL FACE

NOTES:

1. REGRADE EXISTING CHANNEL AND INSTALL CONCRETE RIPRAP STONE PROTECTION. MATCH EXISTING UPSTREAM SECTION, AND TRANSITION CHANNEL FLOWLINE TO MATCH PROPOSED 6'x6' RCB CULVERT INVERT. TRANSITION SIDE-SLOPES TO MATCH PROPOSED 2-6'x4' RCB CULVERT INVERTS. SEE CULVERT LAYOUT FOR LIMITS OF REGRADING AND STONE PROTECTION.



DOWNSTREAM HEADWALL FACE

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KHALIL JOSEPH ABBOUD
104530
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD
HCFCD UNIT No. P240-00-00
CULVERT CROSS-SECTIONS

Texas Department of Transportation

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
5:13:28 PM
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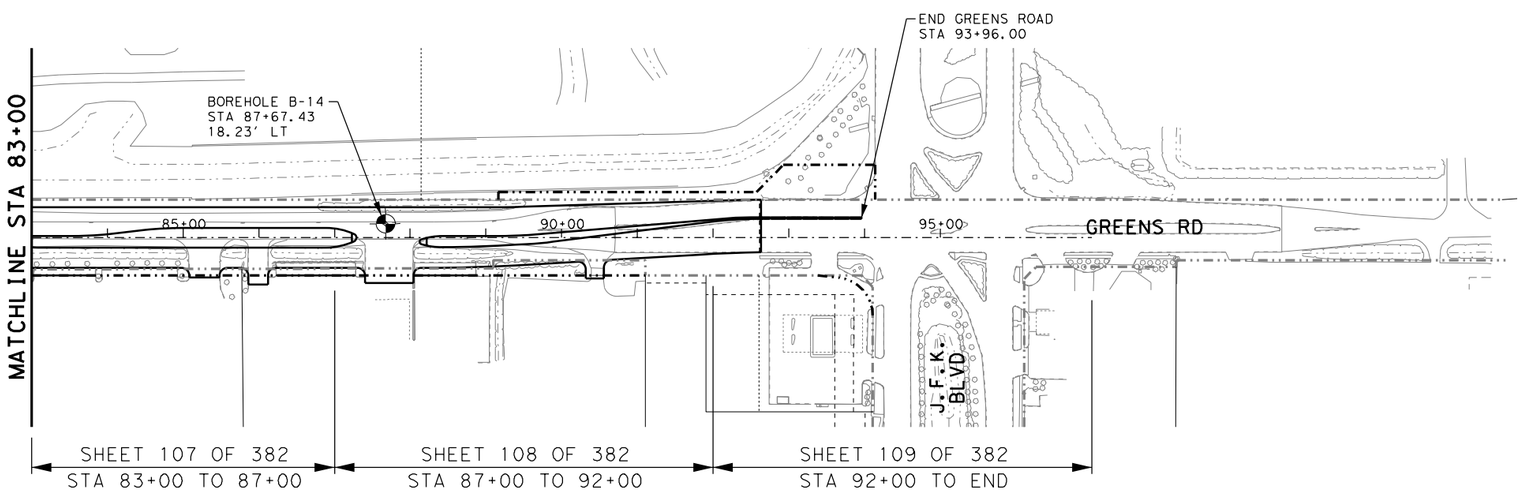
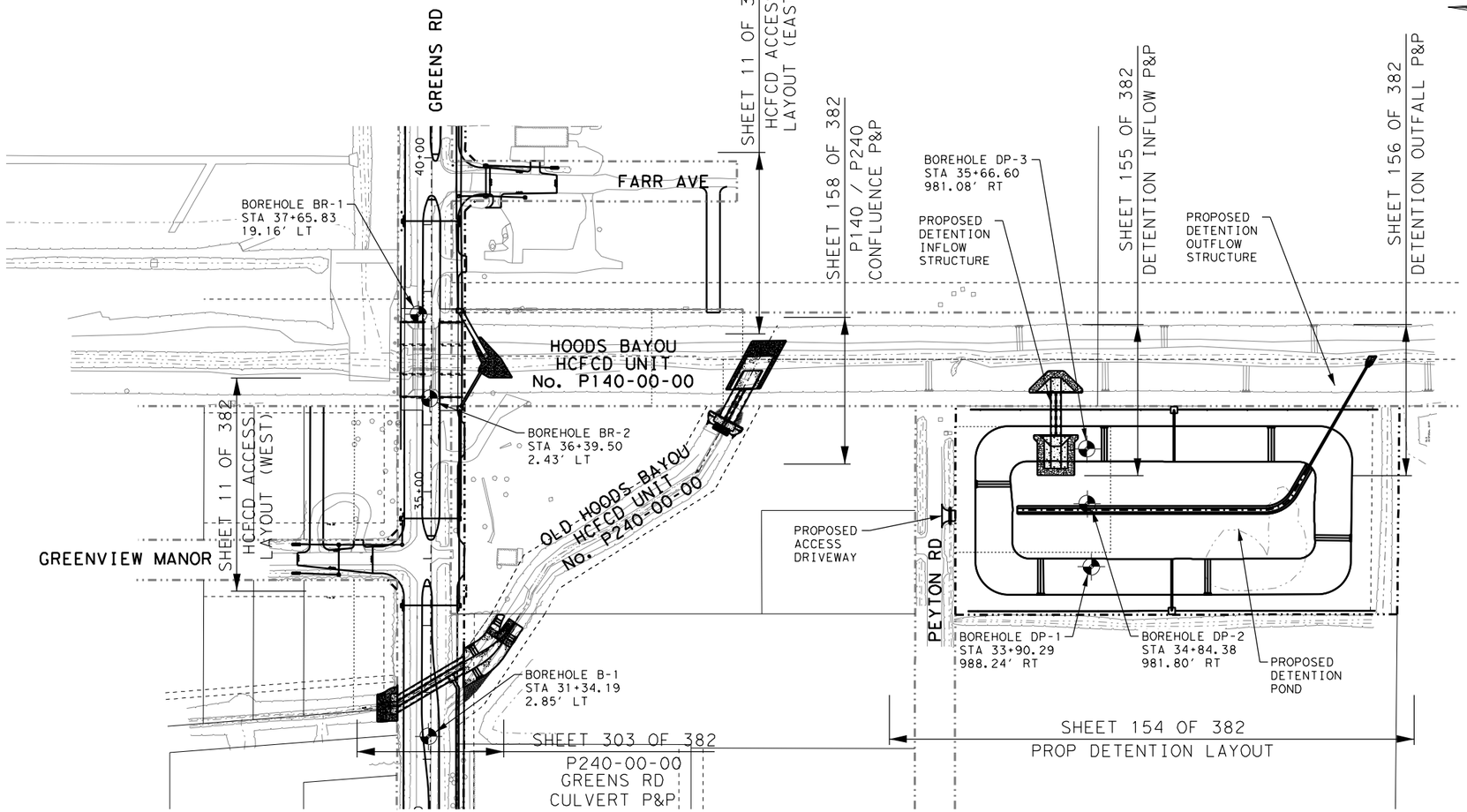
APPENDIX L

PROPOSED DETENTION BASIN SECTION





0 100 200 HORIZ
SCALE IN FEET

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CITY OF HOUSTON
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TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD

PROJECT LAYOUT, SHEET LAYOUT, & BORING LOG LAYOUT

Texas Department of Transportation

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	
TEXAS	HOUSTON	HARRIS	SHEET NO.
CONTROL	SECTION	JOB	
0912	71	739	

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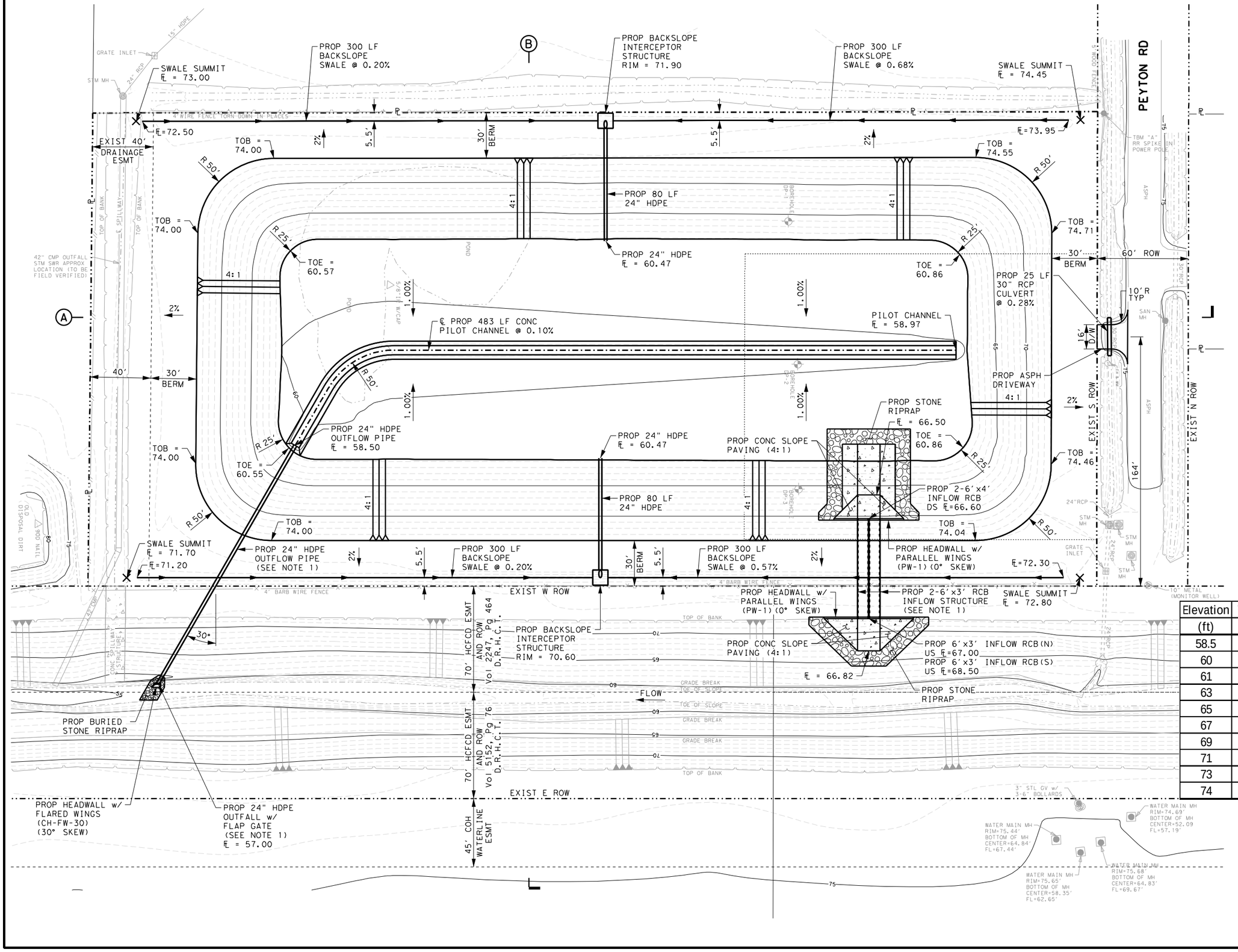

Elevation (ft)	Volume (ac-ft)
58.5	0
60	0.2
61	1.3
63	4.5
65	8.3
67	12.5
69	17.0
71	21.9
73	27.4
74	30.0

LEGEND

- PROP BURIED STONE RIPRAP (GRADATION No. 1)
- PROP CONC CHANNEL LINING
- PROP BACKSLOPE SWALE
- 65 PROP MAJOR CONTOUR (5' INTERVAL)
- PROP MINOR CONTOUR (1' INTERVAL)

BENCHMARK

CITY OF HOUSTON SURVEY MARKER 5465-0512, SOUTHWEST OF GREENS RD AND GREENVIEW MANOR INTERSECTION

X = 13,911,420.53
Y = 3,123,911.11
(GRID COORDINATES)

ELEV = 75.63' (NAVD 88, 2001 ADJ)

SEE SURVEY CONTROL DRAWINGS FOR THE FOLLOWING TEMPORARY BENCHMARK(S): TBM "A"

NOTES:

1. SEE DETENTION INFLOW AND OUTFALL PLAN & PROFILE SHEETS FOR ADDITIONAL INFORMATION FOR STRUCTURES.
2. CONSTRUCT PROPOSED ASPHALT DRIVEWAY IN ACCORDANCE WITH TxDOT STANDARD DETAIL STDB-8.
3. PROPOSED DETENTION POND TO ULTIMATELY BE MAINTAINED BY HCFCD.

0 30 60 HORIZ
SCALE IN FEET

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84713
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD

DETENTION POND LAYOUT

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

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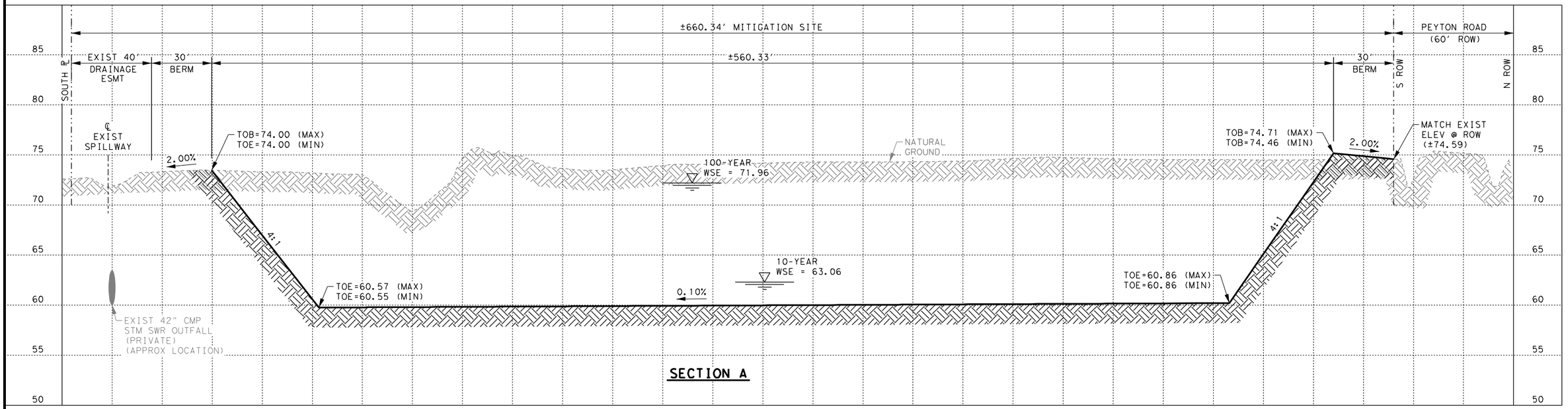
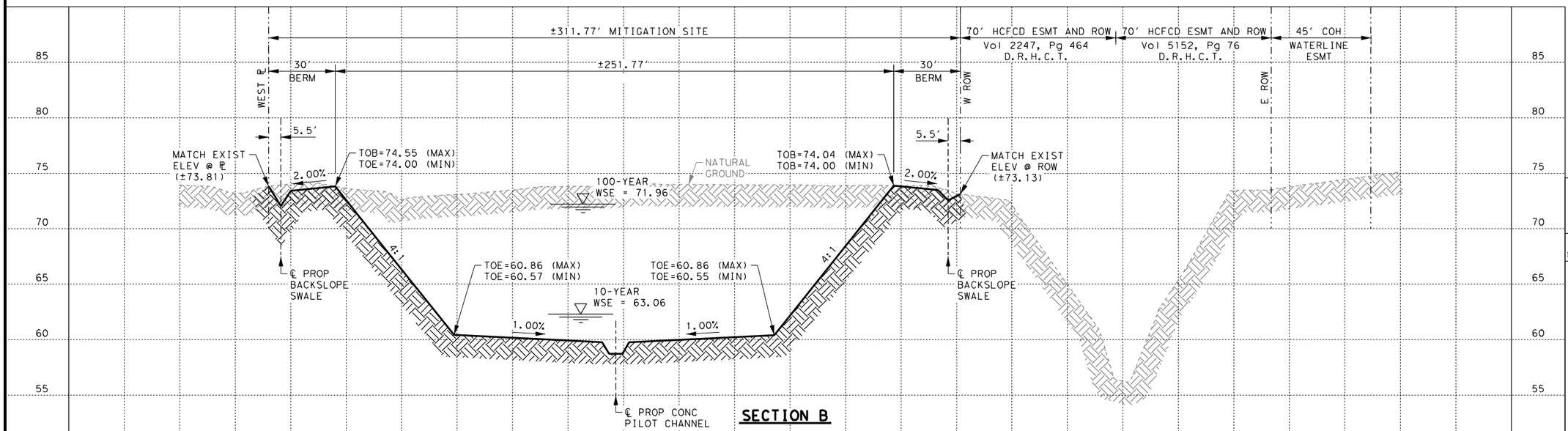
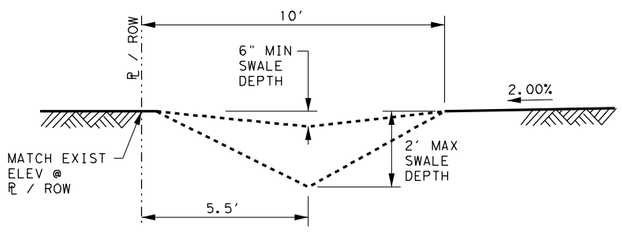


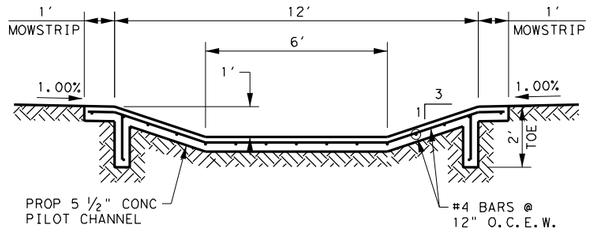
SECTION A



SECTION B



BACKSLOPE SWALE DETAIL



CONCRETE PILOT CHANNEL DETAIL

NOTES:

1. CONTRACTOR SHALL CONSTRUCT CHANNEL LINING AND BURIED STONE RIPRAP IN ACCORDANCE WITH HCFCD STANDARDS AND SPECIFICATIONS (#02376 & #02378). SEE PLAN FOR LIMITS OF CONCRETE CHANNEL LINING AND STONE RIPRAP.
2. CONTRACTOR SHALL CONSTRUCT BACKSLOPE DRAINAGE SYSTEM IN ACCORDANCE WITH HCFCD STANDARDS AND SPECIFICATIONS. EXTEND PIPE 3 FEET PAST PROPOSED TOE OF SLOPE INTO DETENTION POND.
3. HYDROMULCH SEED ALL DISTURBED AREAS (#02921).

0 25 50 HORIZ
0 5 10 VERT
SCALE IN FEET

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84713
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD

DETENTION POND CROSS-SECTIONS

Texas Department of Transportation

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
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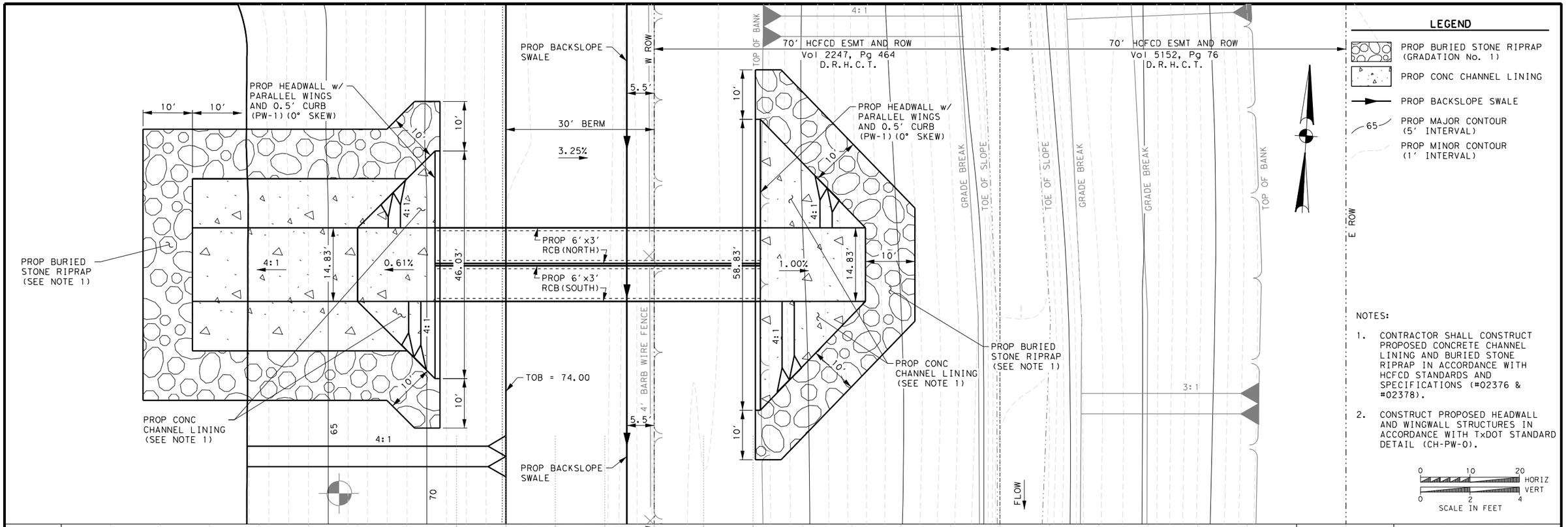

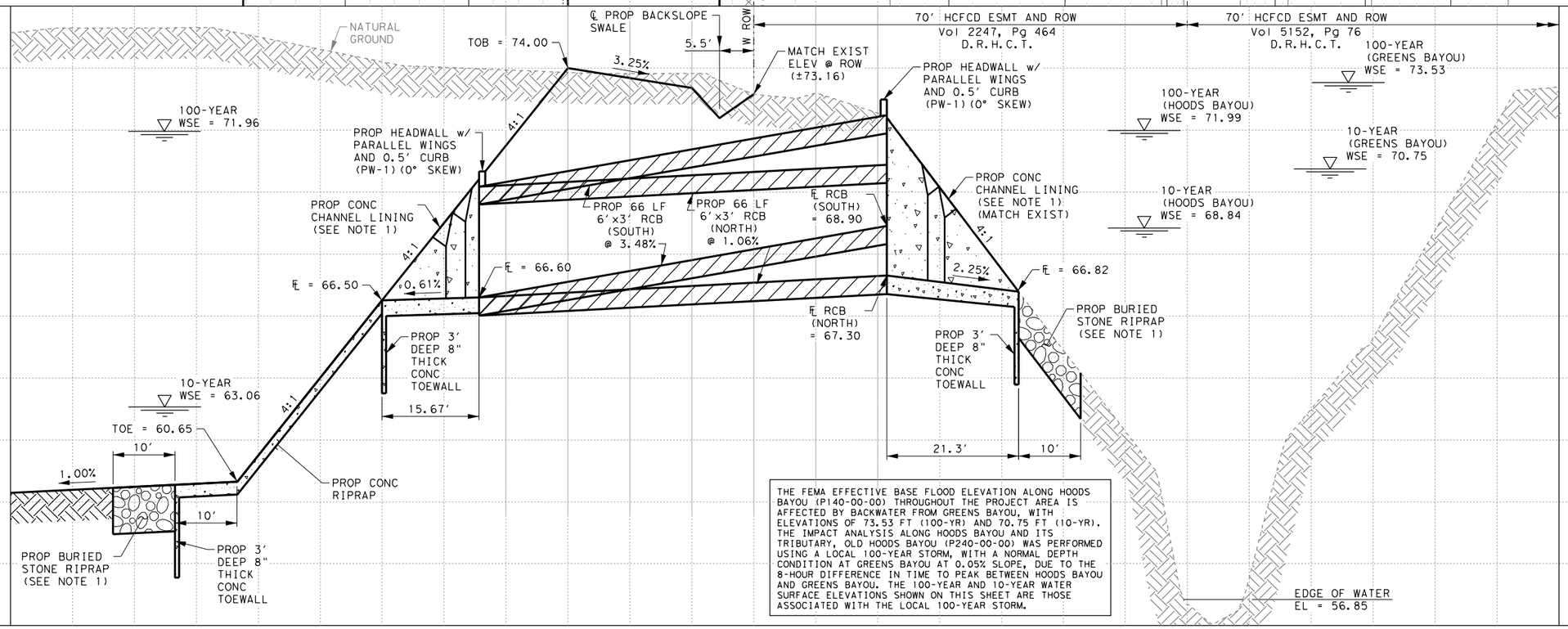

THE FEMA EFFECTIVE BASE FLOOD ELEVATION ALONG HOODS BAYOU (P140-00-00) THROUGHOUT THE PROJECT AREA IS AFFECTED BY BACKWATER FROM GREENS BAYOU, WITH ELEVATIONS OF 73.53 FT (100-YR) AND 70.75 FT (10-YR). THE IMPACT ANALYSIS ALONG HOODS BAYOU AND ITS TRIBUTARY, OLD HOODS BAYOU (P240-00-00) WAS PERFORMED USING A LOCAL 100-YEAR STORM, WITH A NORMAL DEPTH CONDITION AT GREENS BAYOU AT 0.05% SLOPE, DUE TO THE 8-HOUR DIFFERENCE IN TIME TO PEAK BETWEEN HOODS BAYOU AND GREENS BAYOU. THE 100-YEAR AND 10-YEAR WATER SURFACE ELEVATIONS SHOWN ON THIS SHEET ARE THOSE ASSOCIATED WITH THE LOCAL 100-YEAR STORM.

AECOM
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84713
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7/28/2015
DATE

GREENS ROAD

DETENTION POND INFLOW STRUCTURE PLAN & PROFILE

Texas Department of Transportation

SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
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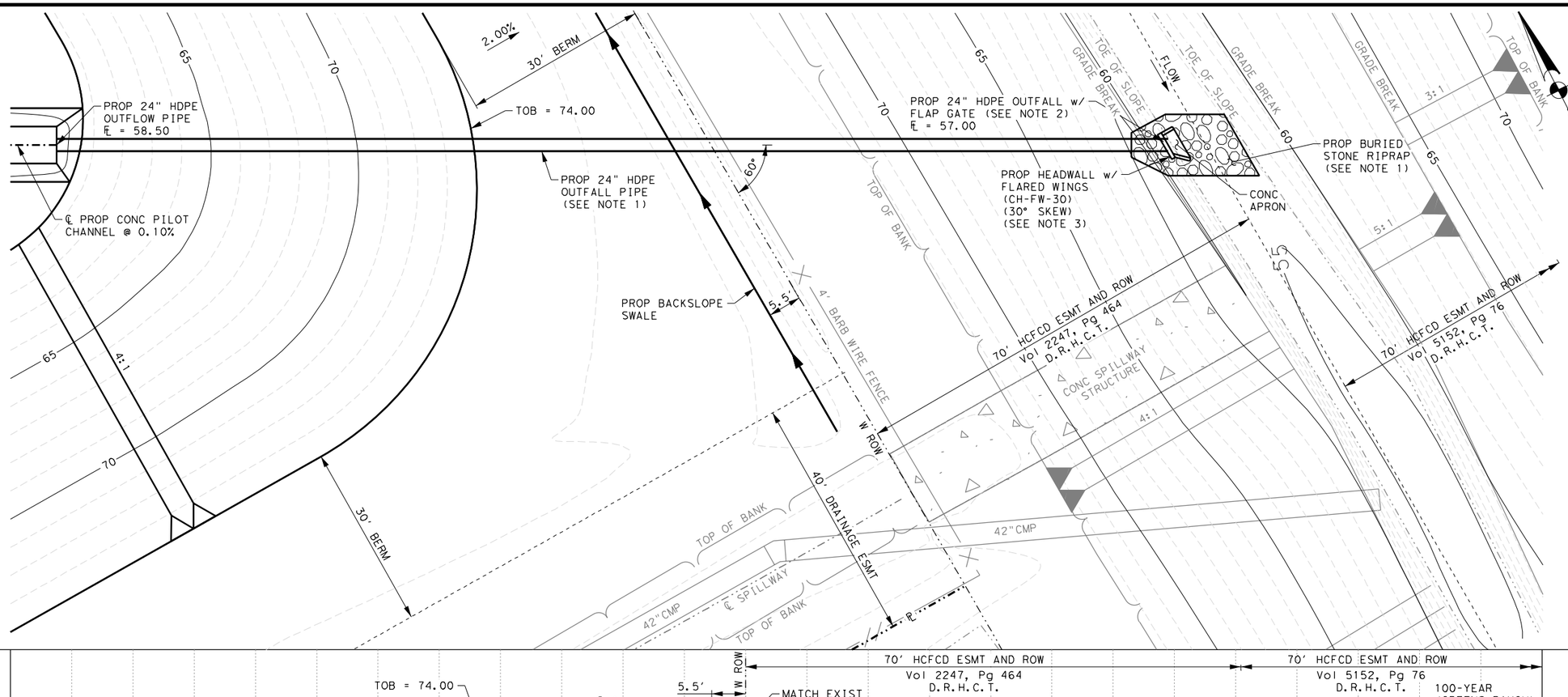

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84713
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD

DETENTION POND OUTFALL STRUCTURE PLAN & PROFILE

Texas Department of Transportation
SHEET OF

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
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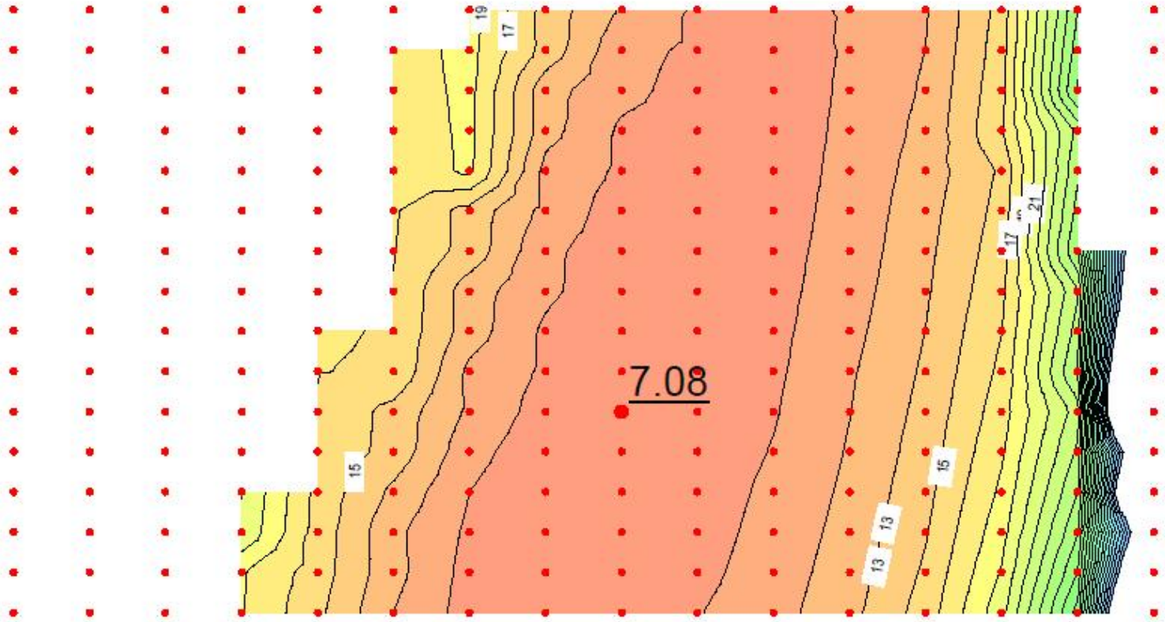
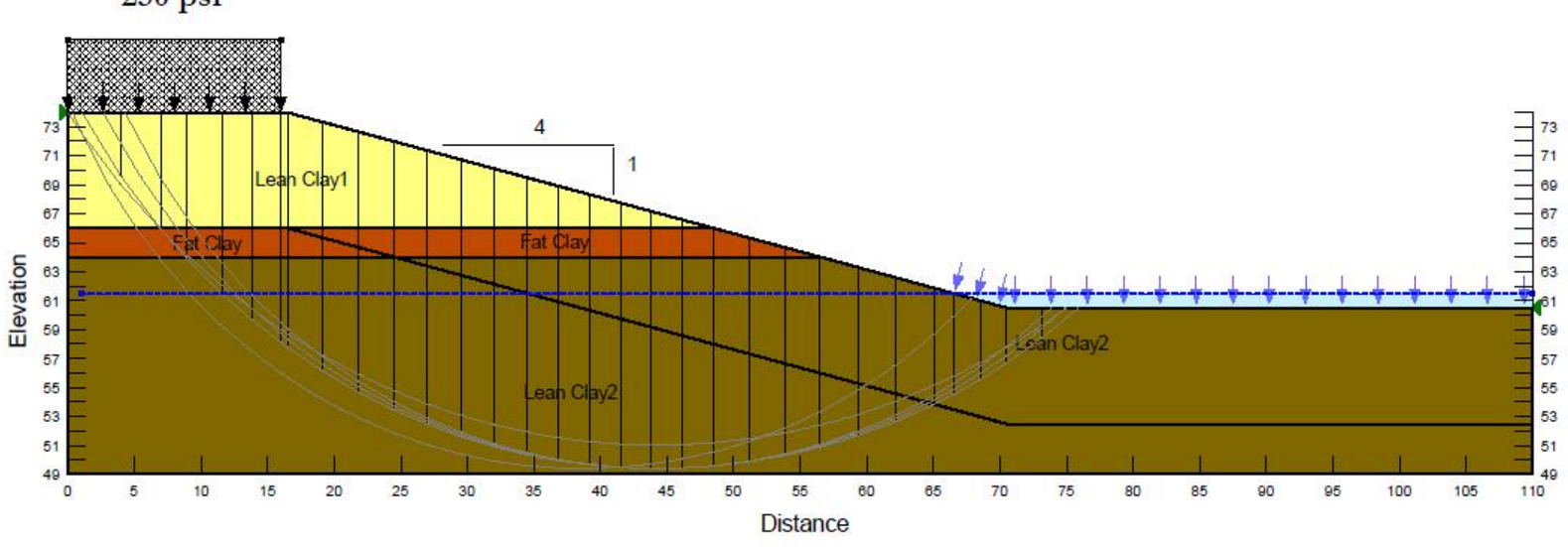
APPENDIX M

DETENTION POND SLOPE STABILITY ANALYSIS



Project Name: Greens Road from Aldine Westfield to JFK
Project Number: HG0519680
Detention Pond
Loading Condition: Short Term
Shear Strength: Undrained



Name: Lean Clay1
Unit Weight: 130 pcf
Cohesion': 1,700 psf

Name: Fat Clay
Unit Weight: 135 pcf
Cohesion': 3,600 psf

Name: Lean Clay2
Unit Weight: 130 pcf
Cohesion': 1,920 psf

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 08/18/14	APPROVED BY: SV	PREPARED BY: SS

GLOBAL STABILITY ANALYSIS (4H:1V)
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE M-1

Slope Stability

File Information

Last Edited By: Sanjeevan Selvaratnam
Revision Number: 126
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/12/2015
Time: 3:00:21 PM
File Name: DP Right Bank - ST.gsz
Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Pond Slope Stability-Final Report\Revision (08122015)\
Last Solved Date: 8/12/2015
Last Solved Time: 3:00:27 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- Lambda
  - Lambda 1: -1
  - Lambda 2: -0.8
  - Lambda 3: -0.6
  - Lambda 4: -0.4
  - Lambda 5: -0.2
  - Lambda 6: 0
  - Lambda 7: 0.2
  - Lambda 8: 0.4

Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: No
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Lean Clay1

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion': 1,700 psf
Pore Water Pressure
Piezometric Line: 1

Fat Clay

Model: Undrained (Phi=0)
Unit Weight: 135 pcf
Cohesion': 3,600 psf
Pore Air Pressure: 62.4 psf
Pore Water Pressure
Piezometric Line: 1

Lean Clay2

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion': 1,920 psf
Pore Water Pressure
Piezometric Line: 1

Slip Surface Grid

Upper Left: (-1, 127.25853) ft
Lower Left: (-1, 85.96591) ft
Lower Right: (84, 85.96591) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (2, 73.84375) ft
Upper Right Coordinate: (10, 73.84375) ft
Lower Left Coordinate: (2, 49.40625) ft
Lower Right Coordinate: (10, 49.40625) ft
Number of Increments: 15
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 74) ft
Right Coordinate: (110, 60.5) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	1	61.5
Coordinate 2	110	61.5

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 50 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	0	79
	16	79

Points

	X (ft)	Y (ft)
Point 1	0	74
Point 2	16.5	74
Point 3	70.5	60.5
Point 4	0	49
Point 5	0	66
Point 6	48.5	66
Point 7	0	64
Point 8	16.5	66
Point 9	24.5	64
Point 10	70.5	52.5
Point 11	56.5	64
Point 12	70.5	49
Point 13	110	52.5
Point 14	110	49
Point 15	110	60.5

Regions

	Material	Points	Area (ft^2)
Region 1	Lean Clay1	1,2,6,8,5	260
Region 2	Fat Clay	5,8,9,7	41
Region 3	Fat Clay	9,8,6,11	64
Region 4	Lean Clay2	9,11,3,15,13,10	556

Region 5	Lean Clay2	7,9,10,13,14,12,4	931.25

Current Slip Surface

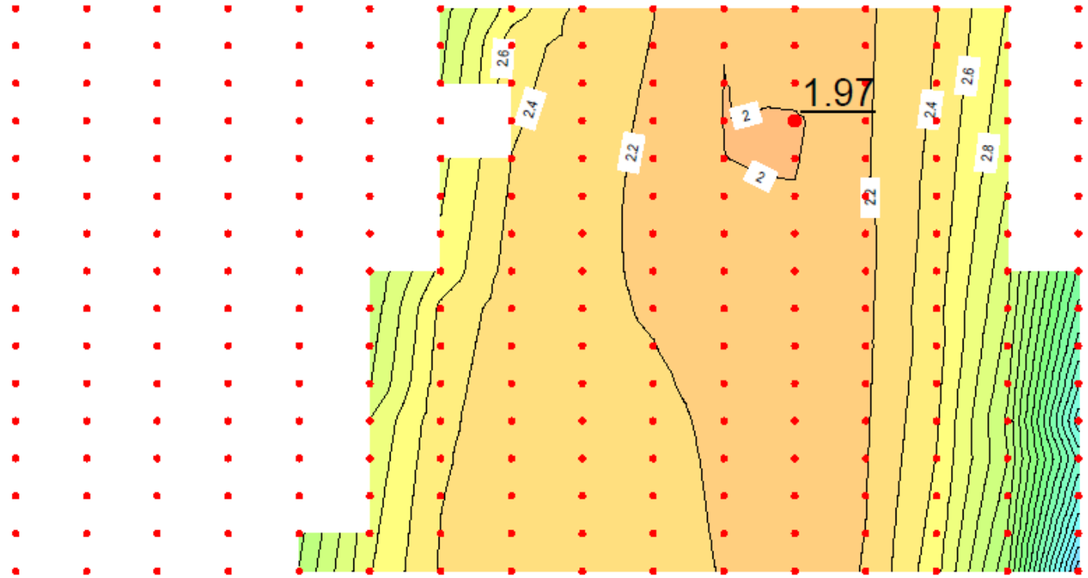
Slip Surface: 1,424
F of S: 7.08
Volume: 979.19515 ft³
Weight: 127,740.96 lbs
Resisting Moment: 8,437,572.7 lbs-ft
Activating Moment: 1,192,537.1 lbs-ft
Resisting Force: 145,463.4 lbs
Activating Force: 20,622.251 lbs
F of S Rank: 1
Exit: (75.853002, 60.5) ft
Entry: (1.0846033, 74) ft
Radius: 50.323867 ft
Center: (44.333333, 99.730117) ft

Slip Slices

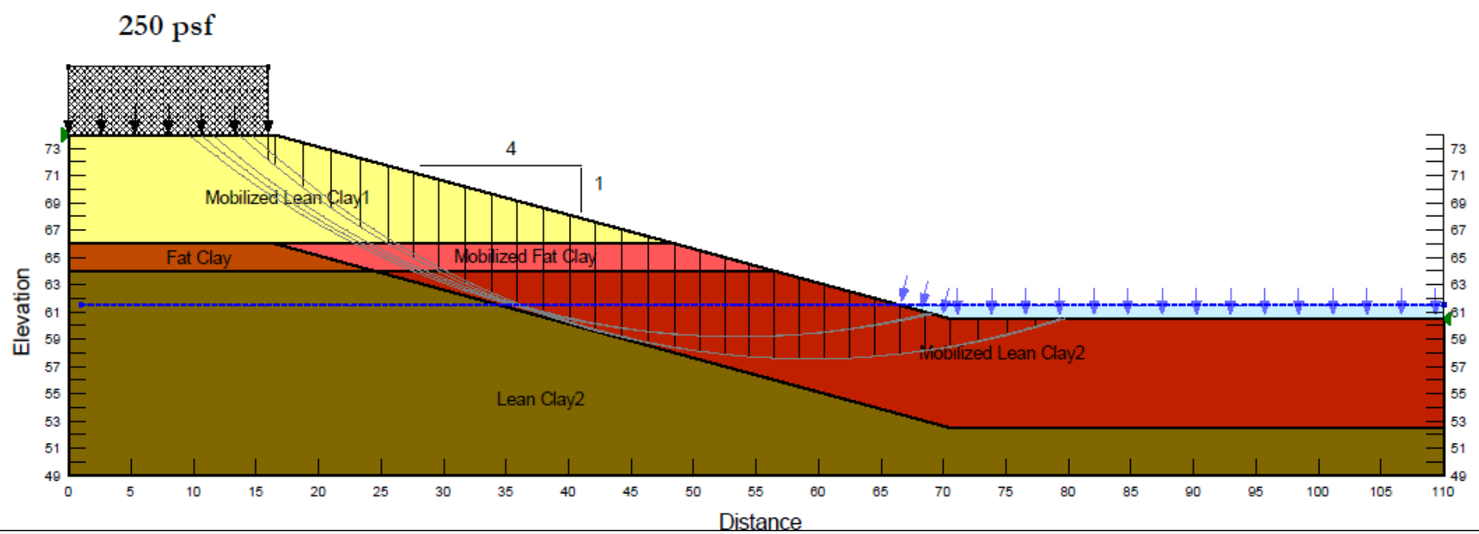
	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	2.5601282	71.793657	-642.32421	177.16673	0	1,700
Slice 2	5.5111782	67.793657	-392.72421	742.03517	0	1,700
Slice 3	7.941029	65	-218.4	863.20915	0	3,600
Slice 4	10.25166	62.75	-78	1,397.6719	0	1,920
Slice 5	12.705974	60.612244	55.395962	1,676.7233	0	1,920
Slice 6	14.901991	58.932389	160.21895	1,896.2115	0	1,920
Slice 7	16.25	57.972157	220.13739	1,785.8988	0	1,920
Slice 8	17.833333	56.977564	282.19999	1,879.109	0	1,920
Slice 9	20.5	55.433713	378.53629	2,010.0469	0	1,920

Slice 10	23.166667	54.097853	461.89398	2,119.9785	0	1,920
Slice 11	25.75	52.982476	531.49347	2,209.0265	0	1,920
Slice 12	28.25	52.063802	588.81876	2,279.4535	0	1,920
Slice 13	30.75	51.291504	637.01018	2,335.2378	0	1,920
Slice 14	33.25	50.658648	676.50039	2,376.4029	0	1,920
Slice 15	35.666667	50.172295	706.8488	2,402.2124	0	1,920
Slice 16	38	49.820224	728.81804	2,413.004	0	1,920
Slice 17	40.333333	49.579127	743.86249	2,409.4063	0	1,920
Slice 18	42.666667	49.447404	752.08198	2,390.529	0	1,920
Slice 19	45	49.424195	753.53024	2,355.3967	0	1,920
Slice 20	47.333333	49.509348	748.21667	2,303.0007	0	1,920
Slice 21	49.833333	49.725694	734.71669	2,224.2913	0	1,920
Slice 22	52.5	50.091712	711.87717	2,115.0096	0	1,920
Slice 23	55.166667	50.605111	679.84109	1,979.4618	0	1,920
Slice 24	57.923635	51.29863	636.5655	1,812.2801	0	1,920
Slice 25	60.770906	52.190357	580.92171	1,610.9199	0	1,920
Slice 26	63.618176	53.273574	513.32901	1,378.2068	0	1,920
Slice 27	65.770906	54.207896	455.02729	1,184.4029	0	1,920
Slice 28	67.5	55.069978	401.2334	1,029.4955	0	1,920

Slice 29	69.5	56.166408	332.81614	850.95856	0	1,920
Slice 30	71.83825	57.618168	242.22629	644.41804	0	1,920
Slice 31	74.514751	59.496115	125.0424	405.39531	0	1,920



- Project Name: Greens Road from Aldine Westfield to JFK
- Project Number: HG0519680
- Detention Pond
- Loading Condition: Long Term
- Shear Strength: Drained



Name: Mobilized Lean Clay1
Unit Weight: 130 pcf
Cohesion': 100 psf
Phi': 22.2 °

Name: Fat Clay
Unit Weight: 135 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Lean Clay2
Unit Weight: 130 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Mobilized Fat Clay
Unit Weight: 135 pcf
Cohesion': 26 psf
Phi': 22.2 °

Name: Mobilized Lean Clay2
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 22.2 °

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 08/18/14	APPROVED BY: SV	PREPARED BY: SS

GLOBAL STABILITY ANALYSIS (4H:1V)
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE M-2

Slope Stability

File Information

Last Edited By: Sanjeevan Selvaratnam
Revision Number: 117
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/12/2015
Time: 2:49:48 PM
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Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Pond Slope Stability-Final Report\Revision (08122015)\
Last Solved Date: 8/12/2015
Last Solved Time: 2:49:55 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- Lambda
  - Lambda 1: -1
  - Lambda 2: -0.8
  - Lambda 3: -0.6
  - Lambda 4: -0.4
  - Lambda 5: -0.2
  - Lambda 6: 0
  - Lambda 7: 0.2
  - Lambda 8: 0.4

Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: No
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Mobilized Lean Clay1

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 100 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Fat Clay

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Air Pressure: 62.4 psf

Pore Water Pressure
Piezometric Line: 1

Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Mobilized Fat Clay

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 26 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Mobilized Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Grid

Upper Left: (-3, 137.35228) ft
Lower Left: (-3, 96.05966) ft
Lower Right: (82, 96.05966) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (2, 73.84375) ft
Upper Right Coordinate: (10, 73.84375) ft
Lower Left Coordinate: (2, 49.40625) ft
Lower Right Coordinate: (10, 49.40625) ft
Number of Increments: 15

Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 74) ft
Right Coordinate: (110, 60.5) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	1	61.5
Coordinate 2	110	61.5

Points

	X (ft)	Y (ft)
Point 1	0	74
Point 2	16.5	74
Point 3	70.5	60.5
Point 4	0	49
Point 5	0	66
Point 6	48.5	66
Point 7	0	64
Point 8	16.5	66
Point 9	24.5	64
Point 10	70.5	52.5
Point 11	56.5	64
Point 12	70.5	49
Point 13	110	52.5
Point 14	110	49
Point 15	110	60.5

Regions

	Material	Points	Area (ft²)
Region 1	Mobilized Lean Clay1	1,2,6,8,5	260
Region 2	Fat Clay	5,8,9,7	41
Region 3	Mobilized Fat Clay	9,8,6,11	64
Region 4	Mobilized Lean Clay2	9,11,3,15,13,10	556
Region 5	Lean Clay2	7,9,10,13,14,12,4	931.25

Current Slip Surface

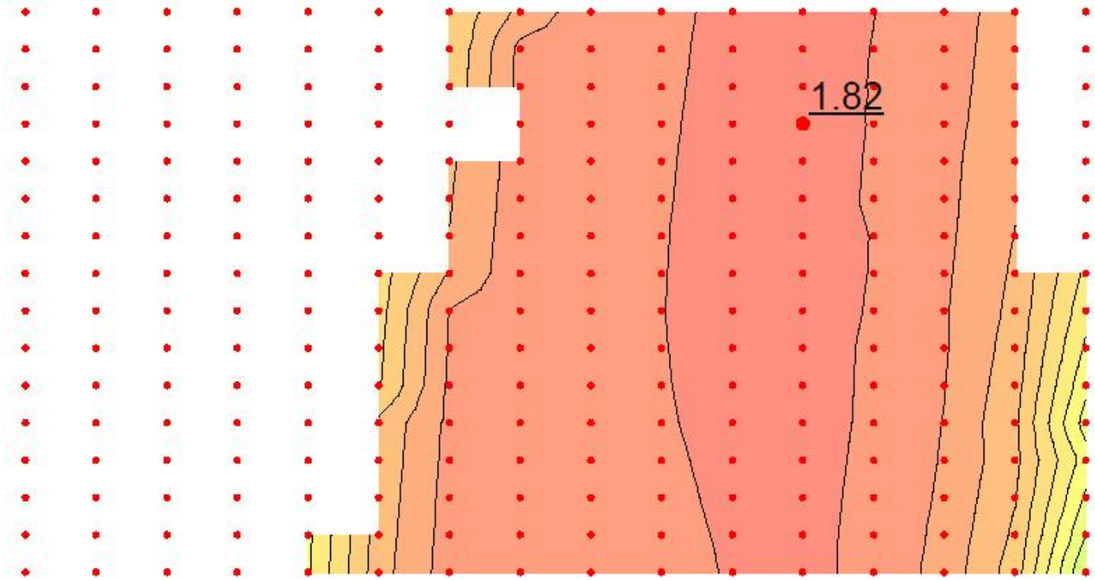
Slip Surface: 3,003
F of S: 2.02
Volume: 327.66949 ft³
Weight: 42,839.626 lbs
Resisting Moment: 1,278,199.1 lbs-ft
Activating Moment: 633,752.36 lbs-ft
Resisting Force: 17,493.91 lbs
Activating Force: 8,676.5336 lbs
F of S Rank: 1
Exit: (79.255112, 60.5) ft
Entry: (14.697787, 74) ft
Radius: 68.788831 ft
Center: (59.333333, 126.34091) ft

Slip Slices

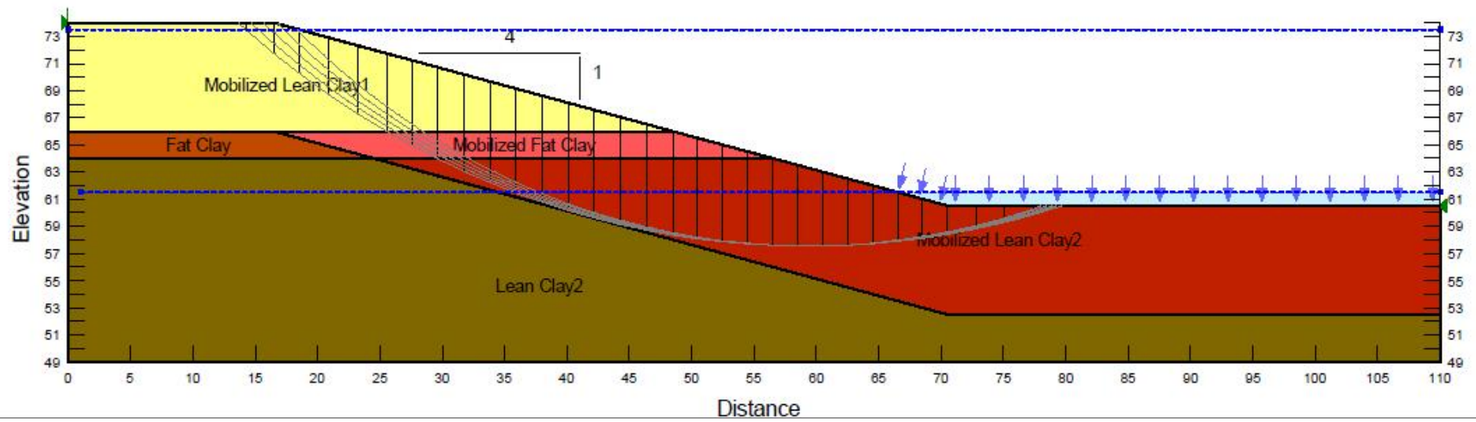
	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	15.598894	73.257594	-733.67386	48.053596	19.610309	100
Slice 2	17.48049	71.763299	-640.42986	189.52498	77.343711	100
Slice 3	19.44147	70.313298	-549.94978	298.25907	121.71727	100
Slice 4	21.402451	68.966967	-465.93872	395.56094	161.42543	100
Slice 5	23.363431	67.717147	-387.94997	482.83218	197.04016	100
Slice 6	25.324411	66.557773	-315.60502	561.21172	229.02626	100

Slice 7	27.29258	65.480028	-248.35374	646.46071	263.81573	26
Slice 8	29.267937	64.480028	-185.95374	712.06358	290.58776	26
Slice 9	31.273793	63.54504	-127.61052	766.59899	312.84325	50
Slice 10	33.310147	62.673912	-73.252118	816.89848	333.3701	50
Slice 11	35.346501	61.878872	-23.641595	860.67832	351.23632	50
Slice 12	37.375955	61.159336	21.257404	898.40342	357.95666	50
Slice 13	39.398509	60.512428	61.624478	929.46826	354.16049	50
Slice 14	41.421062	59.933409	97.755266	953.19664	349.09916	50
Slice 15	43.443616	59.420515	129.75985	969.43616	342.66555	50
Slice 16	45.46617	58.972234	157.73257	977.9227	334.71339	50
Slice 17	47.488723	58.587283	181.75354	978.30235	325.06555	50
Slice 18	49.5	58.266044	201.79885	969.01863	313.09659	50
Slice 19	51.5	58.006962	217.96556	949.68072	298.60743	50
Slice 20	53.5	57.807213	230.42992	921.0624	281.84189	50
Slice 21	55.5	57.666278	239.22427	882.75122	262.61848	50
Slice 22	57.5	57.583795	244.37119	835.68213	241.30953	50
Slice 23	59.5	57.559554	245.88381	779.62888	217.81733	50
Slice 24	61.5	57.593494	243.76599	713.16542	191.55836	50
Slice 25	63.5	57.6857	238.01233	636.28058	162.53026	50

Slice 26	65.5	57.836408	228.60814	549.1178	130.79757	50
Slice 27	67.5	58.046006	215.52924	469.05066	103.46018	50
Slice 28	69.5	58.315038	198.74162	396.23586	80.595905	50
Slice 29	71.594389	58.662758	177.04387	327.67849	61.472849	50
Slice 30	73.783167	59.096193	149.99757	266.26159	47.446468	50
Slice 31	75.971945	59.60421	118.29731	194.6078	31.141735	50
Slice 32	78.160723	60.18853	81.835733	113.27289	12.829267	50



- Project Name: Greens Road from Aldine Westfield to JFK
- Project Number: HG0519680
- Detention Pond
- Loading Condition: Rapid Drawdown
- Shear Strength: Drained



Name: Mobilized Lean Clay1
Unit Weight: 130 pcf
Cohesion': 100 psf
Phi': 22.2 °

Name: Fat Clay
Unit Weight: 135 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Lean Clay2
Unit Weight: 130 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Mobilized Fat Clay
Unit Weight: 135 pcf
Cohesion': 26 psf
Phi': 22.2 °

Name: Mobilized Lean Clay2
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 22.2 °

HVJ ASSOCIATES
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DATE: 08/18/14	APPROVED BY: SV	PREPARED BY: SS

GLOBAL STABILITY ANALYSIS (4H:1V)
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE M-3

Slope Stability

File Information

Last Edited By: Sanjeevan Selvaratnam
Revision Number: 112
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/12/2015
Time: 2:44:22 PM
File Name: DP Right Bank - RDD.gsz
Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Pond Slope Stability-Final Report\Revision (08122015)\
Last Solved Date: 8/12/2015
Last Solved Time: 2:44:32 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
Side Function
Interslice force function option: Half-Sine
Lambda
Lambda 1: -1
Lambda 2: -0.8
Lambda 3: -0.6
Lambda 4: -0.4
Lambda 5: -0.2
Lambda 6: 0
Lambda 7: 0.2
Lambda 8: 0.4

Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: Yes
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Mobilized Lean Clay1

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 100 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 101 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 2
Piezometric Line After Drawdown: 1

Fat Clay

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 350 psf

Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 351 psf
Total Phi: 22.1 °
Pore Air Pressure: 62.4 psf
Pore Water Pressure
Piezometric Line: 2
Piezometric Line After Drawdown: 1

Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 351 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 2
Piezometric Line After Drawdown: 1

Mobilized Fat Clay

Model: Mohr-Coulomb
Unit Weight: 135 pcf
Cohesion': 26 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 27 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 2
Piezometric Line After Drawdown: 1

Mobilized Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion': 50 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 98 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 2
Piezometric Line After Drawdown: 1

Slip Surface Grid

Upper Left: (-3, 137.35228) ft
Lower Left: (-3, 96.05966) ft
Lower Right: (82, 96.05966) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (2, 73.84375) ft
Upper Right Coordinate: (10, 73.84375) ft
Lower Left Coordinate: (2, 49.40625) ft
Lower Right Coordinate: (10, 49.40625) ft
Number of Increments: 15
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 74) ft
Right Coordinate: (110, 60.5) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	1	61.5
Coordinate 2	110	61.5

Piezometric Line 2

Coordinates

	X (ft)	Y (ft)
Coordinate 1	0	73.5
Coordinate 2	110	73.5

Points

	X (ft)	Y (ft)
Point 1	0	74
Point 2	16.5	74
Point 3	70.5	60.5
Point 4	0	49
Point 5	0	66
Point 6	48.5	66
Point 7	0	64
Point 8	16.5	66
Point 9	24.5	64
Point 10	70.5	52.5
Point 11	56.5	64
Point 12	70.5	49
Point 13	110	52.5
Point 14	110	49
Point 15	110	60.5

Regions

	Material	Points	Area (ft²)
Region 1	Mobilized Lean Clay1	1,2,6,8,5	260
Region 2	Fat Clay	5,8,9,7	41
Region 3	Mobilized Fat Clay	9,8,6,11	64
Region 4	Mobilized Lean Clay2	9,11,3,15,13,10	556
Region 5	Lean Clay2	7,9,10,13,14,12,4	931.25

Current Slip Surface

Slip Surface: 3,259
F of S: 1.82
Volume: 339.15151 ft³
Weight: 44,338.799 lbs
Resisting Moment: 1,237,169.5 lbs-ft
Activating Moment: 680,137.42 lbs-ft
Resisting Force: 16,483.895 lbs
Activating Force: 9,062.634 lbs
F of S Rank: 1
Exit: (79.658381, 60.5) ft

Entry: (13.694655, 74) ft
Radius: 71.541673 ft
Center: (59.333333, 129.09376) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	13.999858	73.75	-764.4	-10.316582	-4.2101192	100
Slice 2	15.402531	72.64589	-695.50353	118.78291	0	133.54298
Slice 3	17.5	71.070801	-597.21796	263.01261	107.33346	100
Slice 4	19.684689	69.560824	-502.99543	380.51744	0	230.23599
Slice 5	22.054068	68.048359	-408.61763	491.82649	0	254.20548
Slice 6	24.423447	66.662446	-322.13663	588.6965	0	275.0729
Slice 7	26.618967	65.480164	-248.36221	689.15075	0	200.40126
Slice 8	28.640626	64.480164	-185.96221	753.56242	0	216.21295
Slice 9	30.692261	63.545226	-127.62209	797.15452	0	306.46495
Slice 10	32.773872	62.67426	-73.273822	846.34292	0	318.16564
Slice 11	34.855483	61.879034	-23.651735	888.15948	0	328.96075
Slice 12	36.946598	61.153914	21.595738	922.92928	0	338.95358
Slice 13	39.047216	60.49722	62.573473	950.65627	0	348.12674
Slice 14	41.147835	59.910527	99.183127	971.08024	0	356.33878
Slice 15	43.248453	59.392065	131.53512	984.01683	0	363.42987

Slice 16	45.349072	58.940321	159.72394	989.17981	0	369.17715
Slice 17	47.449691	58.554012	183.82966	986.13913	0	373.30343
Slice 18	49.5	58.238289	203.53078	973.24166	314.11319	50
Slice 19	51.5	57.989342	219.06505	950.987	298.69182	50
Slice 20	53.5	57.797357	231.0449	919.82951	281.08779	50
Slice 21	55.5	57.661875	239.49899	879.47759	261.17043	50
Slice 22	57.5	57.582574	244.44739	830.96802	239.35464	50
Slice 23	59.5	57.559267	245.90175	774.15389	215.5757	50
Slice 24	61.5	57.591899	243.86551	707.6621	189.27188	50
Slice 25	63.5	57.680547	238.33386	631.48736	160.44297	50
Slice 26	65.5	57.82542	229.29377	545.72991	129.1352	50
Slice 27	67.5	58.026863	216.72375	467.51148	102.34458	50
Slice 28	69.5	58.285358	200.59365	396.98677	80.146548	50
Slice 29	71.644798	58.628955	179.15322	330.30468	61.683769	50
Slice 30	73.934393	59.067672	151.77727	269.18496	47.913192	50
Slice 31	76.223988	59.584557	119.52365	197.222	31.708111	50
Slice 32	78.513583	60.181371	82.282468	114.80843	13.273598	50

Project Name: Greens Road
Project Number:HG0519680

By: ND Date: 09/23/2014
Check'd By: SS Date 09/24/2014

Lean Clay1 - Effective

Linear Shear Strength Parameter Evaluation (Mesri & Abdel-Ghaffar, 1993)		
Plasticity Index, PI	21	No reduction if PI < 20
Strength Reduction Ratio, η	0.96	From Fig. 13, Mesri & Abdel-Ghaffar, 1993
Effective Friction Angle, φ' (deg)	22.2	From CU Test or Fig. 1 of Mesri-Ghaffar, 1993
Effective Cohesion, c (psf)	350	From CU Test
Maximum Depth of Active Zone, (ft)	8	
Effective Unit Weight, γ', (pcf)	130	
Is $c'_{peak} \geq \sigma'_n (1-\eta) \tan\varphi'_{peak} / \eta$?	YES	
Peak Shear Strength, τ, (psf)	774.4	
c'_{mob} (psf)	319.0	
φ'_{mob} (degrees)	22.2	

Input Parameters
Calculated Parameters

For explanation of the procedure, see attached.

Project Name: Greens Road
Project Number:HG0519680

By: SS Date: 09/23/2014
Check'd By: ND Date 09/24/2014

Lean Clay2 - Effective

Linear Shear Strength Parameter Evaluation (Mesri & Abdel-Ghaffar, 1993)

Plasticity Index, PI	28	No reduction if PI < 20
Strength Reduction Ratio, η	0.68	From Fig. 13, Mesri & Abdel-Ghaffar, 1993
Effective Peak Friction Angle, φ' (deg)	22.2	From CU Test or Fig. 1 of Mesri-Ghaffar, 1993
Effective Peak Cohesion, c (psf)	350	From CU Test
Maximum Depth of Active Zone, (ft)	8	
Effective Unit Weight, γ', (pcf)	135	
Is $c'_{peak} \geq \sigma'_n (1-\eta) \tan\varphi'_{peak} / \eta$?	YES	
Peak Shear Strength, τ, (psf)	790.7	
c'_{mob} (psf)	97.0	
φ'_{mob} (degrees)	22.2	

Input Parameters
Calculated Parameters

For explanation of the procedure, see attached.

Project Name: Greens Road
Project Number:HG0519680

By: ND Date: 09/23/2014
Check'd By: SS Date 09/24/2014

Fat Clay - Effective

Linear Shear Strength Parameter Evaluation (Mesri & Abdel-Ghaffar, 1993)

Plasticity Index, PI	31	No reduction if PI < 20
Strength Reduction Ratio, η	0.59	From Fig. 13, Mesri & Abdel-Ghaffar, 1993
Effective Peak Friction Angle, φ' (deg)	22.2	From CU Test or Fig. 1 of Mesri-Ghaffar, 1993
Effective Peak Cohesion, c (psf)	350	From CU Test
Maximum Depth of Active Zone, (ft)	8	
Effective Unit Weight, γ', (pcf)	135	
Is $c'_{peak} \geq \sigma'_n (1-\eta) \tan\varphi'_{peak} / \eta$?	YES	
Peak Shear Strength, τ, (psf)	790.7	
c'_{mob} (psf)	25.8	
φ'_{mob} (degrees)	22.2	

Input Parameters
Calculated Parameters

For explanation of the procedure, see attached.

The limiting normal stress is based on the depth of the active zone and the depth of the static water table. For HCFCD projects the active zone is limited to the top 8 feet, and the limiting effective normal stress is shown below assuming γ = 125 pcf and water table depth > 8 feet. The method will be illustrated based on HCFCD assumptions.

$$\sigma'_n = (125 \text{ pcf})(8 \text{ feet}) = 1000 \text{ psf} \qquad \text{(A-3)}$$

From (1),

$$c'_{mob} = \eta \times c'_{peak} - (1-\eta) \times \sigma'_n \tan\varphi'_{peak}$$

For c'_{mob} to be meaningful, it must be greater than or equal to zero, therefore:

$$\eta \times c'_{peak} \geq (1-\eta) \times \sigma'_n \tan\varphi'_{peak}$$

For the depth of influence of 8 feet,

$$c'_{peak} \geq 1000\ (1-\eta)\ \tan\varphi'_{peak} / \eta \qquad \text{(A-4)}$$

If (A-4) is true, use the following:

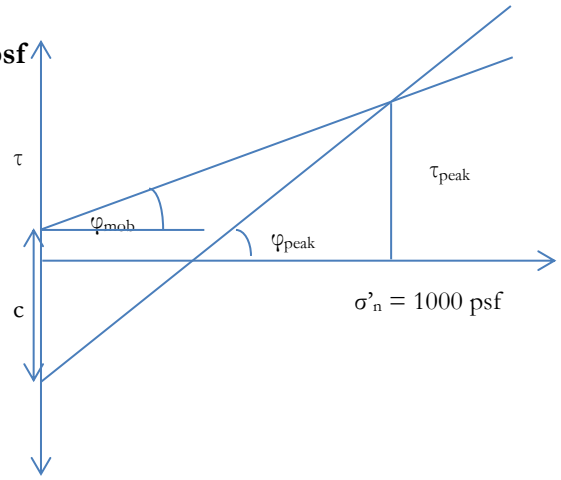
$$\mathbf{c'_{mob} = \eta \times c'_{peak} - (1-\eta) \times \sigma'_n \tan\varphi'_{peak}}$$
$$\mathbf{\varphi'_{peak} = \varphi'_{mob}}$$

If (A-4) is untrue then c'_{mob} would need to be negative in order to achieve the required mobilized shear strength with $\varphi'_{peak} = \varphi'_{mob.}$ We refer to Fig. 14 and the associated discussion in Mesri & Ghaffar (1993) on page 1242 and 1243:

> *…For a large number of higher plasticity soft to stiff clays, c'(mob) = 0, as compared to high values of c'. In some of the latter cases, a value of φ'(mob) less than φ' corresponds to the computed s(mob), suggesting that even for the first time failures, a mobilized shear strength less than the fully softened strength defined by s = σ'„tanφ' may be available…*

Therefore, it would be reasonable to reduce c'_{mob} between 25 psf and 50 psf based on our experience and feedback by HCFCD on prior reports by HVJ Associates at instances where a meaningful c'_{mob} is unattainable as our assumption that $\varphi'_{peak} = \varphi'_{mob}$ may not be true. Under these circumstances, evaluate φ'_{mob} according to the steps below (see figure on the right):

$$\mathbf{c'_{mob} = \eta \times c'_{peak} + \eta \times \sigma'_n tan\varphi'_{peak} - \sigma'_n tan\varphi'_{mob} = 25\ psf}$$



Therefore,

$\varphi'_{mob} = \tan^{-1}\{\mathbf{[\eta \times \tau'_{peak} - 25\ psf]/[\sigma'_n]}\}$

$\tau_{peak} = c'_{peak} + \sigma'_n tan\varphi'_{peak}$ where $\sigma'_n = 1000$ psf

Hence, use the following:

$\mathbf{c'_{mob} = 25\ psf}$

$\varphi'_{mob} = \tan^{-1}\{\mathbf{[\eta \times \tau'_{peak} - 25\ psf]/[\sigma'_n]}\}$

Summary

1. Determine PI, c_{peak}, ϕ_{peak}
2. If PI ≤ 20 use c_{peak} and ϕ_{peak} in analysis
3. If PI > 20:
    a. Select η based on PI from Table 1
    b. Calculate σ'_n (1-η) $tan\varphi'_{peak}$/ η where σ'_n is the effective overburden pressure at the bottom of the active zone.
    c. If $c_{peak} \geq \sigma'_n$ (1-η) $tan\varphi'_{peak}$/ η then
        i. $c'_{mob} = c'_{peak} - \sigma'_n$ (1-η) $tan\varphi'_{peak}$/ η
        ii. $\phi'_{mob} = \phi'_{peak}$
    d. If $c_{peak} < \sigma'_n$ (1-η) $tan\varphi'_{peak}$/ η then
        i. c'_{mob} = 25 to 50 psf
        ii. $\phi'_{mob} = \tan^{-1}\{ [\eta \times \tau'_{peak} - c'_{mob}]/[\sigma'_n]\}$
        where
        $\tau_{peak} = c'_{peak} + \sigma'_n tan\varphi'_{peak}$

Example Calculation:

Consider an actual CU Test Data:

c'_{peak} = 192.5 psf; φ'_{peak} = 21.2 degrees; PI = 39

Therefore from Figure 13, Mesri & Ghaffar, 1993;

η = 0.55

From (A-4), check if $c'_{peak} \geq 1000$ (1-η) $tan\varphi'_{peak}$/ η

or 192.5 ≥ 1000 x (1-0.55) x tan(21.2)/0.55

=> 192.5 ≥ 317.4 **NOT TRUE**

Therefore, we reduce the cohesion to zero based on the discussions above and in the paper (Mesri & Ghaffar, 1993) and obtain φ'_{mob}

$\varphi'_{mob} = \tan^{-1}\{[\eta \times \tau'_{peak} - 25]/[\sigma'_n]\} = \tan^{-1}\{[0.55 \times (192.5 \text{ psf} + 1000 \text{ psf} \times \tan(21.2)) - 25 \text{ psf}]/[1000 \text{ psf}]\}$

$\varphi'_{mob} = 16.4$ degrees

The shear strength parameters to be used are,

$c'_{mob} = 25$ psf; $\varphi'_{mob} = 16.4$ degrees

Rapid Drawdown: Staged Rapid Drawdown using Duncan, Wright, & Wong (1990). The total strength parameters can be obtained by following the same steps as that of the steps for effective strength parameters explained earlier in this document.

Example Calculation:

Consider an actual CU Test Data:

$c_{cu} = 300.6$ psf; $\varphi_{cu} = 14.8$ degrees; PI = 39

Therefore from Figure 13, Mesri & Ghaffar, 1993;

$\eta = 0.55$

From (A-4), check if $c_{cu} \geq 1000 (1-\eta) \tan\varphi_{cu}/ \eta$

or $300.6 \geq 1000 \times (1-0.55) \times \tan(14.8)/0.55$

$\Rightarrow 300.6 \geq 216.2$ **TRUE**

Therefore,

$c_{mob} = c_{cu} - \sigma_n (1-\eta) \tan\varphi_{cu}/\eta = 300.6 - 1000 \times (0.45) \times \tan(14.8)/0.55 = 84.4$ psf

The total shear strength parameters to be used are,

$c_{mob} = 84.4$ psf; $\varphi_{mob} = 14.8$ degrees

References:

Mesri, G. and Abdel-Ghaffar M. E. M., (1993). Cohesion Intercept in Effective Stress-Stability Analysis, *Journal of Geotechnical Engineering,* Vol. 119, No. 8, pp. 1229-1249.

Duncan, J. M., Wright, S. G., and Wong, K. S. (1990). Slope Stability during Rapid Drawdown, *H. Bolton Seed Memorial Proceedings,* Vol. 2.

APPENDIX N

TRAFFIC TP&P DATA

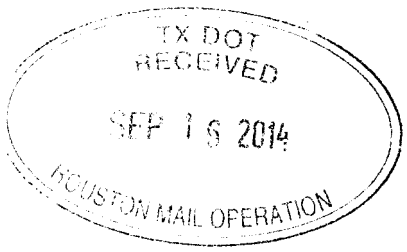
Texas Department of Transportation

MEMO

September 15, 2014

To: Michael Alford, P.E.
Attention: Bill Brudnick, P.E.

From: William E. Knowles, P.E.



Subject: Traffic Data
CSJ: 0912-72-158
Greens Road:
From Aldine-Westfield Road
To JFK Blvd.

Harris County

Attached are tabulations showing traffic analysis for highway design for the 2014 to 2034 twenty year period and 2014 to 2044 thirty year period for the described limits of the route. Included are tabulations showing data for use in air and noise analysis.

Due to significant differences in traffic volumes this project was separated into two sections.

Section-1: From Aldine-Westfield Road to Milner Road
Section-2: From Milner Road to JFK Blvd.

Please refer to your original memorandum dated July 18, 2014.

If you have any questions or need additional information, please contact Robert Williams at (512) 486-5145.

Attachments

CC: Jinsan Lee, P.E., Houston District Design Division

TRAFFIC ANALYSIS FOR HIGHWAY DESIGN

Houston District **September 10, 2014**

Description of Location	Average Daily Traffic 2014	Average Daily Traffic 2034	Base Year Dir Dist %	Base Year K Factor	Base Year Percent Trucks ADT	Base Year Percent Trucks DHV	ATHWLD	Percent Tandem Axles in ATHWLD	Total Number of Equivalent 18k Single Axle Load Applications One Direction Expected for a 20 Year Period (2014 to 2034) Flexible Pavement	S N	Rigid Pavement	SLAB
Greens Road Section 1 From Aldine-Westfield Road To Milner Road Harris County	13,900	19,100	61 - 39	10.1	5.3	4.0	11,100	40	2,114,000	3	2,594,000	8"

Data for Use in Air & Noise Analysis

Vehicle Class	Base Year % of ADT	Base Year % of DHV
Light Duty	94.7	96.0
Medium Duty	3.3	2.5
Heavy Duty	2.0	1.5

Description of Location	Average Daily Traffic 2014	Average Daily Traffic 2044	Base Year Dir Dist %	Base Year K Factor	Base Year Percent Trucks ADT	Base Year Percent Trucks DHV	ATHWLD	Percent Tandem Axles in ATHWLD	Total Number of Equivalent 18k Single Axle Load Applications One Direction Expected for a 30 Year Period (2014 to 2044) Flexible Pavement	S N	Rigid Pavement	SLAB
Greens Road Section 1 From Aldine-Westfield Road To Milner Road Harris County	13,900	21,700	61 - 39	10.1	5.3	4.0	11,100	40	3,421,000	3	4,198,000	8"

TRAFFIC ANALYSIS FOR HIGHWAY DESIGN

Houston District **September 10, 2014**

Description of Location	Average Daily Traffic 2014	Average Daily Traffic 2034	Base Year Dir Dist %	Base Year K Factor	Base Year Percent Trucks ADT	Base Year Percent Trucks DHV	ATHWLD	Percent Tandem Axles in ATHWLD	Total Number of Equivalent 18k Single Axle Load Applications One Direction Expected for a 20 Year Period (2014 to 2034) Flexible Pavement	SN	Rigid Pavement	SLAB
Greens Road Section 2 From Milner Road To JFK Blvd. Harris County	3,400	4,700	61 - 39	10.1	4.2	3.2	10,000	50	413,000	3	506,000	8"

Data for Use in Air & Noise Analysis

Vehicle Class	Base Year % of ADT	Base Year % of DHV
Light Duty	95.8	96.8
Medium Duty	2.6	2.0
Heavy Duty	1.6	1.2

Description of Location	Average Daily Traffic 2014	Average Daily Traffic 2044	Base Year Dir Dist %	Base Year K Factor	Base Year Percent Trucks ADT	Base Year Percent Trucks DHV	ATHWLD	Percent Tandem Axles in ATHWLD	Total Number of Equivalent 18k Single Axle Load Applications One Direction Expected for a 30 Year Period (2014 to 2044) Flexible Pavement	SN	Rigid Pavement	SLAB
Greens Road Section 2 From Milner Road To JFK Blvd. Harris County	3,400	5,300	61 - 39	10.1	4.2	3.2	10,000	50	666,000	3	815,000	8"

NOT INTENDED FOR CONSTRUCTION
BIDDING OR PERMIT PURPOSES
William Erick Knowles, P.E
Serial Number 84704

APPENDIX O

DARWIN OUTPUTS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

Greens Road
HG-05-19680
JRCP over Hot Mix Asphalt Base - 30 years

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	4,198,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	620 psi
28-day Mean Elastic Modulus of Slab	5,000,000 psi
Mean Effective k-value	300 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.9
Overall Drainage Coefficient, Cd	0.95
Calculated Design Thickness	8.65 in

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Rigid Structural Design Module

Greens Road
HG-05-19680
JRCP over Lime Stabilized Subgrade - 30 years

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	4,198,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	620 psi
28-day Mean Elastic Modulus of Slab	5,000,000 psi
Mean Effective k-value	24 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.9
Overall Drainage Coefficient, Cd	0.95
Calculated Design Thickness	9.59 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	2,500	20,000

Base Type	Lime Stabilized Subgrade
Base Thickness	8 in
Depth to Bedrock	100 ft
Projected Slab Thickness	8 in
Loss of Support Category	2
Effective Modulus of Subgrade Reaction	24 psi/in

APPENDIX P

LIME SERIES TEST RESULTS

HVJ ASSOCIATES

Houston
Austin
Dallas
San Antonio

6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010
281.933.7388 Ph
281.933.7293 Fax
www.hvj.com

Estimate of Soil-Lime Proportion using pH ASTM D-6276

REPORT DATE : 8/18/2014

REPORT NO. : HG-05-19680

SAMPLE NO. : N/A

PROJECT: Greens Road HG-05-19680

SAMPLED BY : Steve Weiman

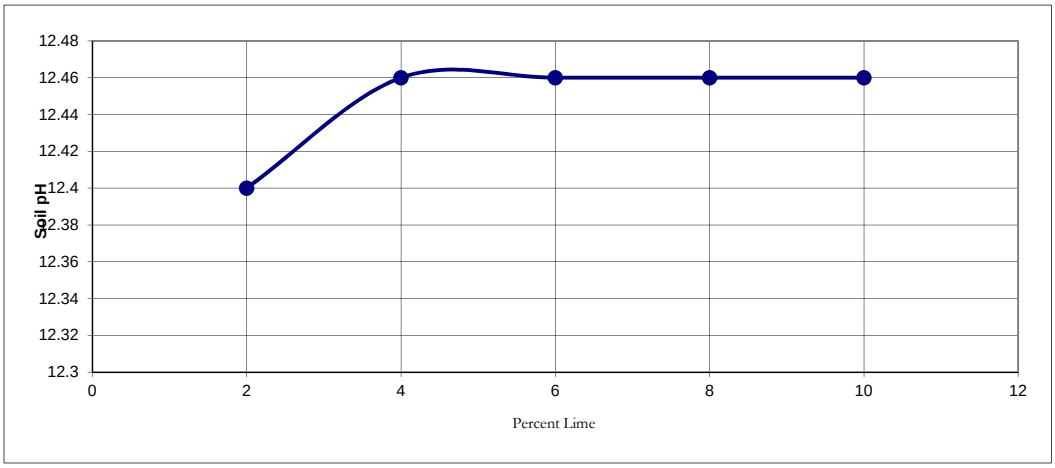
SAMPLE DATE:

LOCATION : Composite samples from B-4, B-6 and B-12 at 2-4'

DATE TESTED: 8/18/14

LIME CURVE
ASTM D-6276
(Soil pH vs Percent of Lime)

Percent of Lime	2	4	6	8	10
Soil pH	12.40	12.46	12.46	12.46	12.46

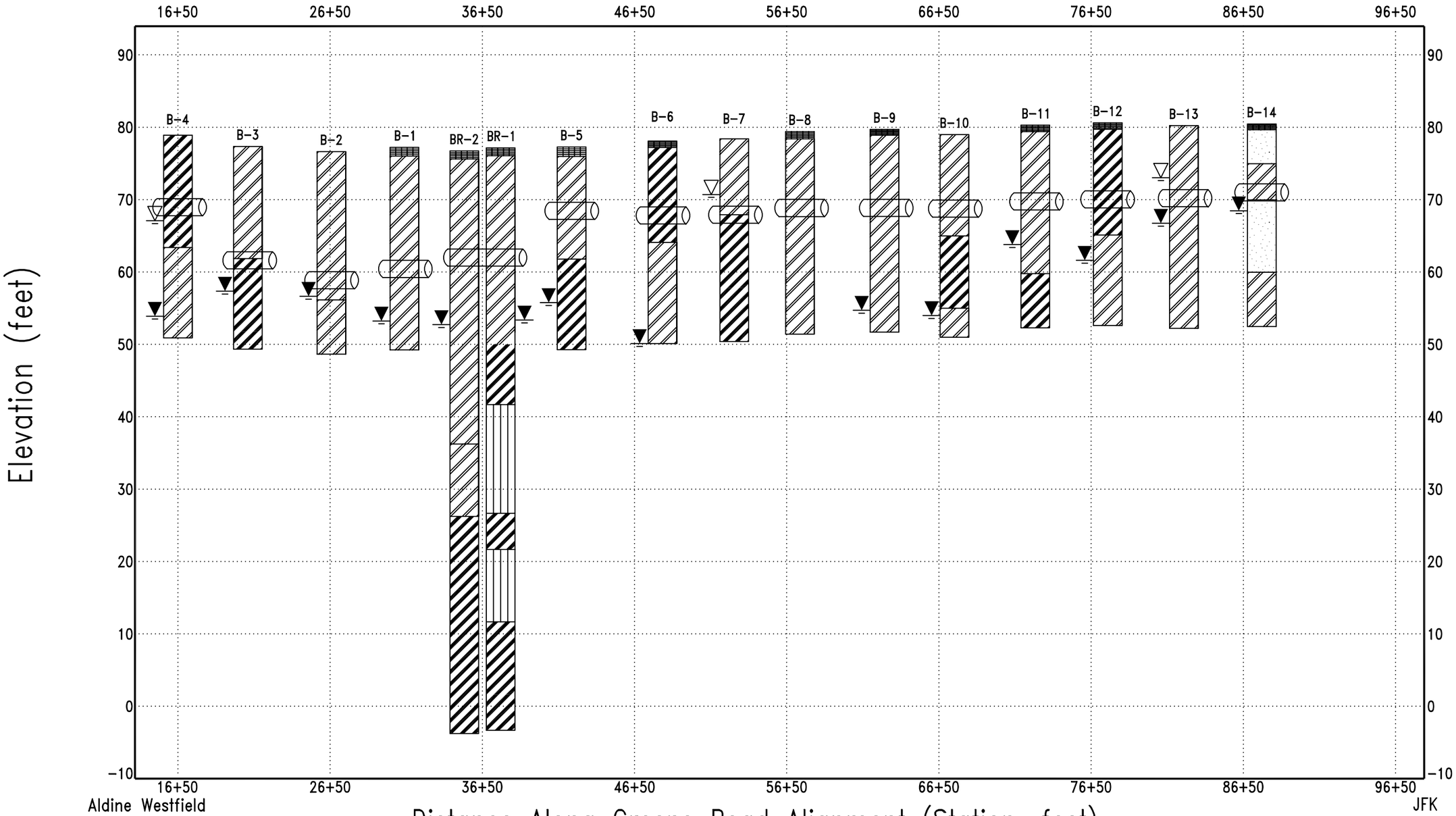


SAMPLE DESCRIPTION: Fat Clay (CH)

MIN. % LIME ESTIMATED: **6%**

APPENDIX Q

BORING LOG SOIL PROFILE



LEGEND:

- Pavement
- Fat Clay (CH)
- Lean Clay (CL) / Silty Clay (CL-ML)
- Silt (ML)
- Clayey Sand (SC)

APPROXIMATE INVERT ELEVATION OF DEEPEST UTILITY (PROVIDED BY AECOM ON 1/20/2015)

GROUNDWATER ELEVATION ENCOUNTERED DURING DRILLING

24 HOUR PIEZOMETER READING

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

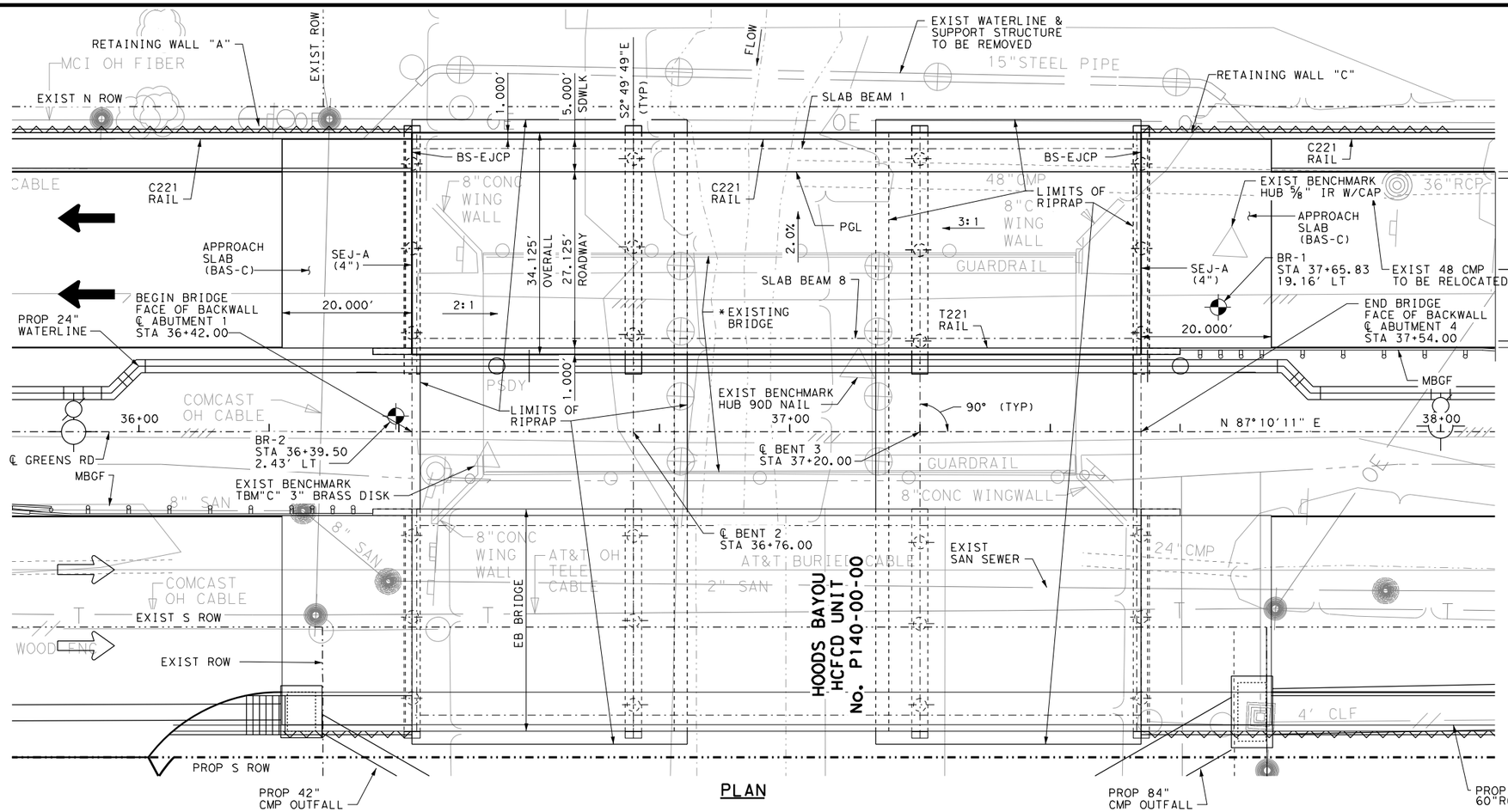
DATE: 1/21/2015	APPROVED BY: ND	PREPARED BY: RS

BORING LOG PROFILE
Greens Road from Aldine Westfield to JFK
WBS No.: N-000686-0002-3

PROJECT NO.:	DRAWING NO.:
HG0519680	PLATE Q-1

APPENDIX R

PROPOSED HOODS BAYOU CROSS SECTIONS



PLAN

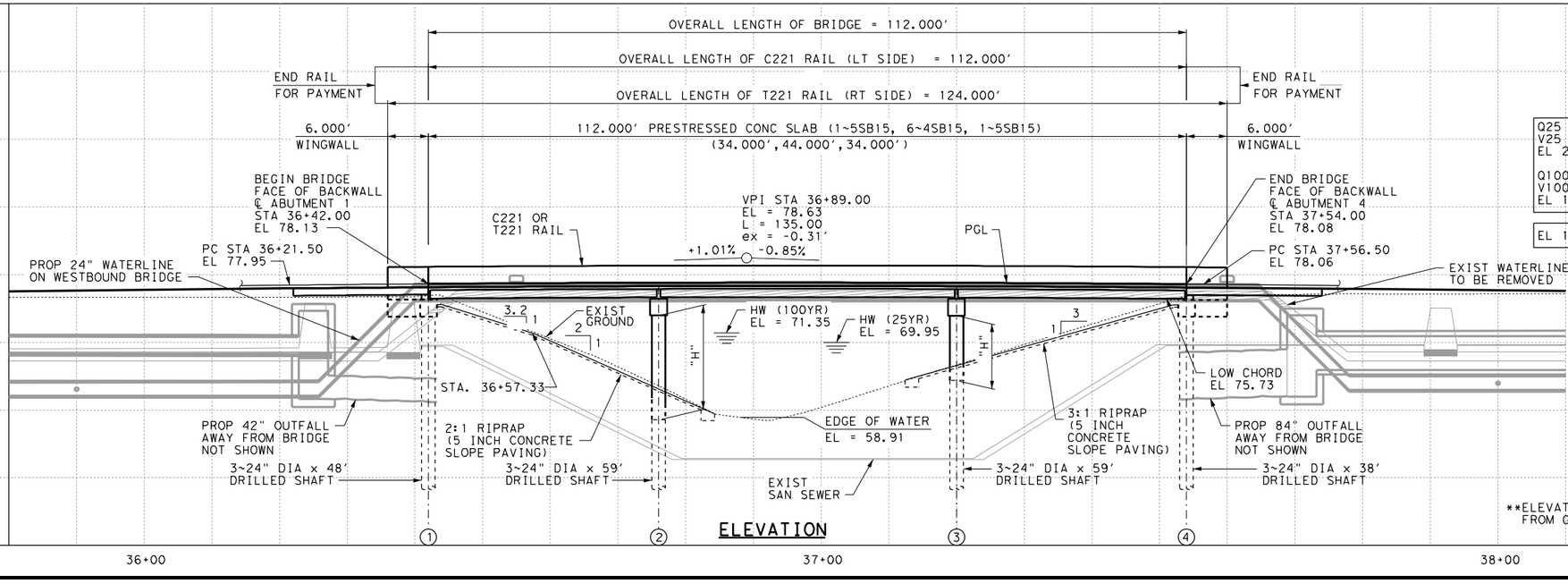
NOTES:

1. DESIGNED IN ACCORDANCE WITH THE LATEST AASHTO LRFD SPECIFICATIONS AND INTERIMS FOR HL-93 LOADING.
2. DESIGN SPEED = 45 mph
   ADT 2015 = 13,900
   ADT 2035 = 19,100
   FUNCTIONAL CLASSIFICATION: URBAN MINOR ARTERIAL.
3. CONTRACTOR SHALL CALL TO VERIFY UTILITIES BEFORE DRILLING OPERATIONS.
4. NBI's:
   EXISTING # 12-102-B286-49-503
   WESTBOUND # XX-XXX-XXXX-XX-XXX
   EASTBOUND # XX-XXX-XXXX-XX-XXX
5. SEE BENT DETAIL SHEETS FOR "H".

*EXISTING 3 SPAN CONCRETE SLAB AND GIRDER (PAN FORM) BRIDGE TO BE REMOVED.

0 10 20

HL93 LOADING



ELEVATION

Q25 =1859 cfs
V25 = 4.28 fps
EL 25 yr = 69.95

Q100 =2567 cfs
V100 = 4.81 fps
EL 100 yr = 71.35

EL 100 yr = 73.53**

**ELEVATION BASED ON BACKWATER FROM GREENS BAYOU (P100-00-00)

AECOM
AECOM TECHNICAL SERVICES, INC.- F-3082

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
WALLY R. BURNS
44162
TEXAS SERIAL NO.
7/28/2015
DATE

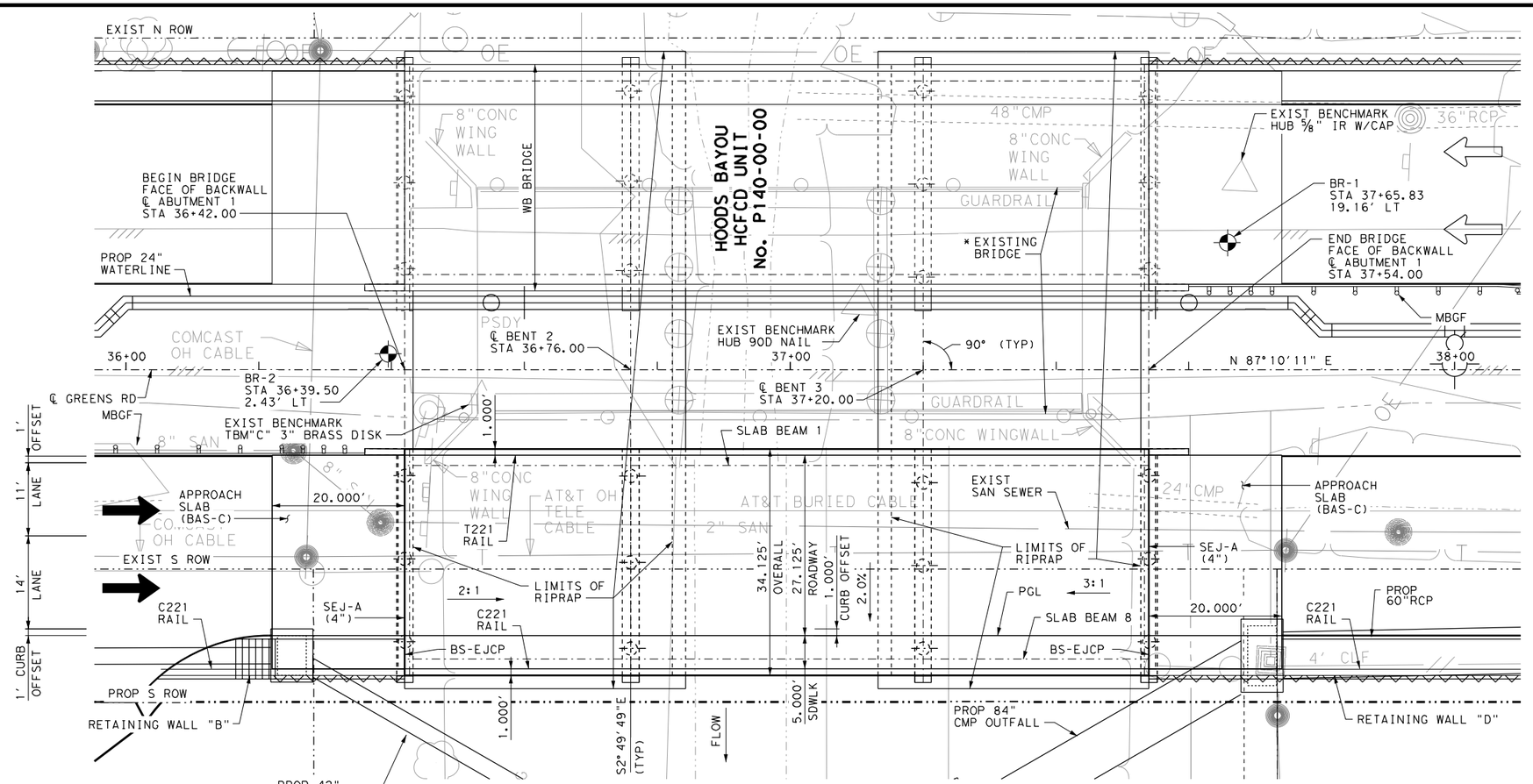
GREENS ROAD

BRIDGE LAYOUT WESTBOUND HOODS BAYOU

Texas Department of Transportation

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	
TEXAS	HOUSTON	HARRIS	SHEET NO.
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
5:17:12 PM
P:*PWD\City of Houston\60178890 - GreensRD-West\900 Cadd\Sheet\GRBL01.dgn



PLAN

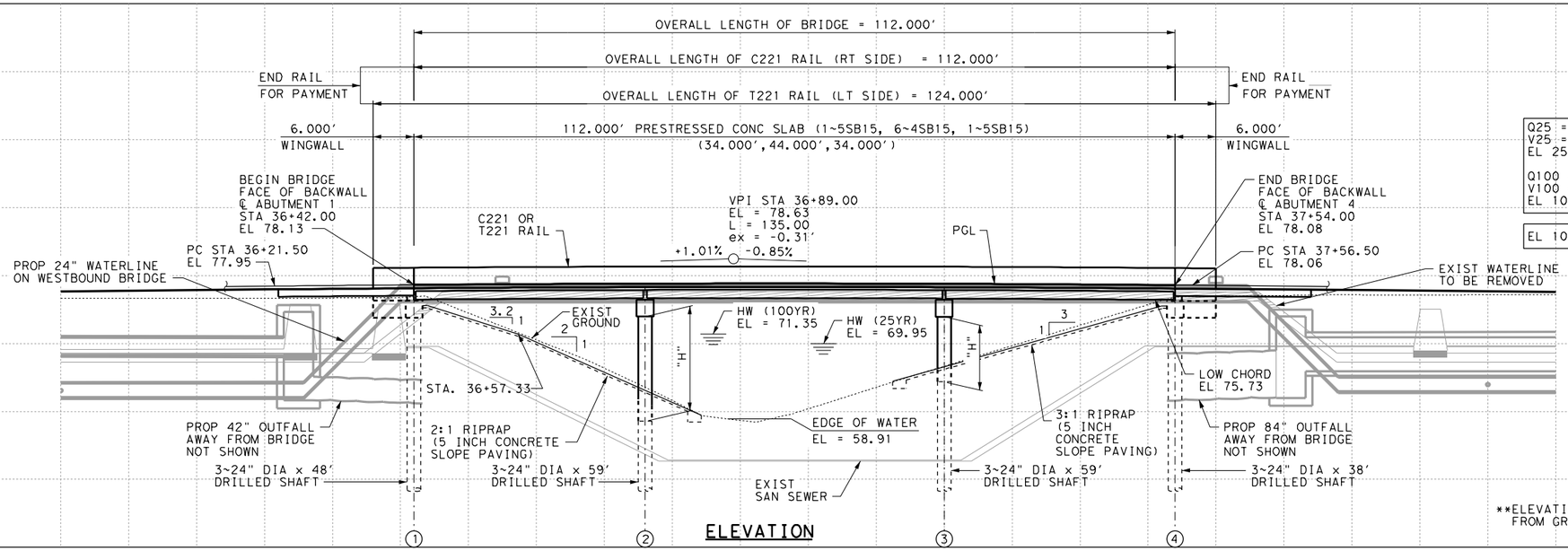
NOTES:

1. DESIGNED IN ACCORDANCE WITH THE LATEST AASHTO LRFD SPECIFICATIONS AND INTERIMS FOR HL-93 LOADING.
2. DESIGN SPEED = 45 mph
   ADT 2015 = 13,900
   ADT 2035 = 19,100
   FUNCTIONAL CLASSIFICATION: URBAN MINOR ARTERIAL.
3. CONTRACTOR SHALL CALL TO VERIFY UTILITIES BEFORE DRILLING OPERATIONS.
4. NBI's:
   EXISTING # 12-102-B286-49-503
   WESTBOUND # XX-XXX-XXXX-XX-XXX
   EASTBOUND # XX-XXX-XXXX-XX-XXX
5. SEE BENT DETAIL SHEETS FOR "H".

* EXISTING 3 SPAN CONCRETE SLAB AND GIRDER (PAN FORM) BRIDGE TO BE REMOVED.

0 10 20

HL93 LOADING



ELEVATION

Q25 =1859 cfs
V25 = 4.28 fps
EL 25 yr = 69.95

Q100 =2567 cfs
V100 = 4.81 fps
EL 100 yr = 71.35

EL 100 yr = 73.53**

**ELEVATION BASED ON BACKWATER FROM GREENS BAYOU (P100-00-00)

AECOM
AECOM TECHNICAL SERVICES, INC. - F-3082

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
WALLY R. BURNS
44162
TEXAS SERIAL NO.
7/28/2015
DATE

GREENS ROAD

BRIDGE LAYOUT EASTBOUND HOODS BAYOU

Texas Department of Transportation

FED RD DIV NO	STATE PROJECT No.		HIGHWAY
6	XXXXX		GREENS RD
STATE	DISTRICT	COUNTY	SHEET NO.
TEXAS	HOUSTON	HARRIS	
CONTROL	SECTION	JOB	
0912	71	739	

7/28/2015
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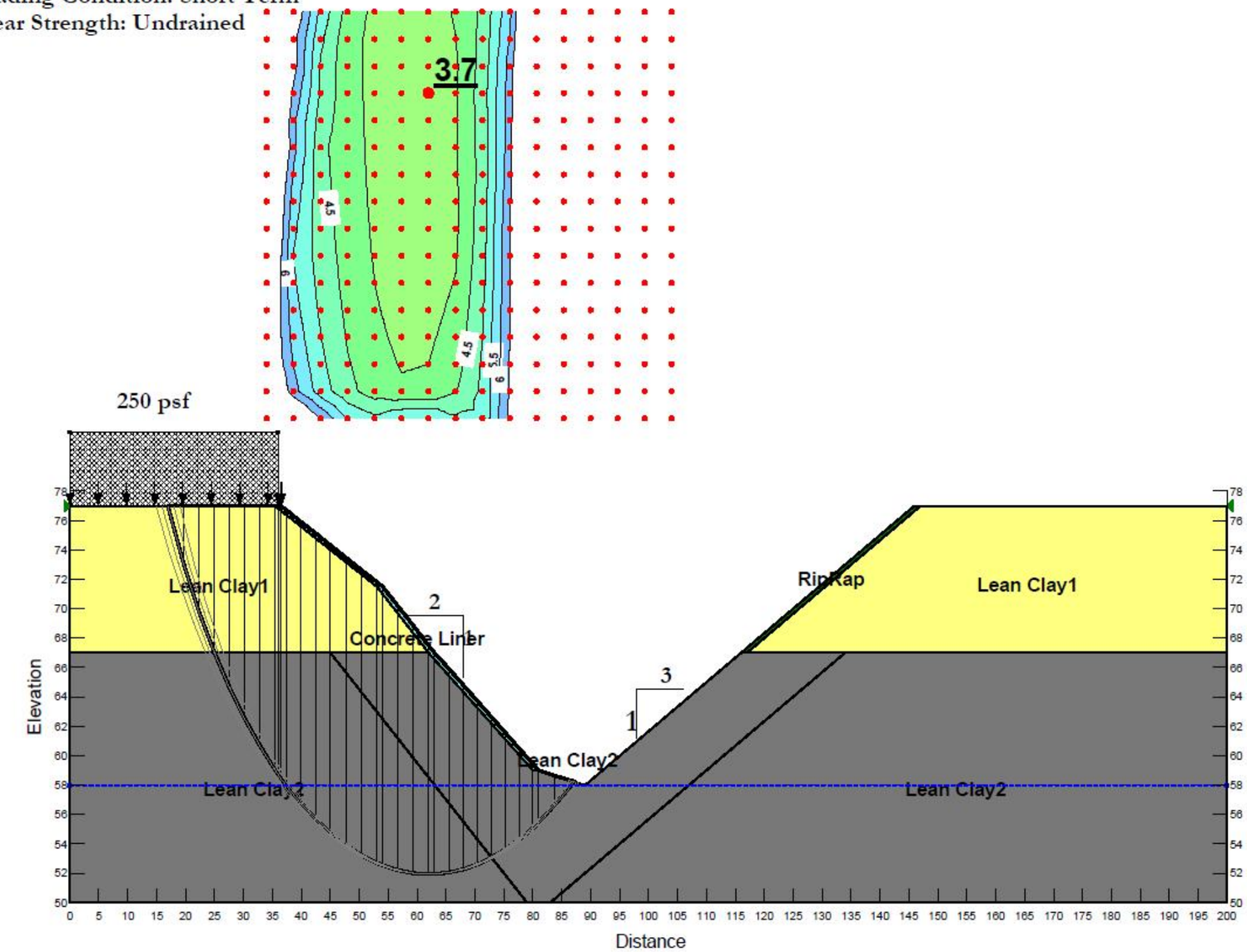
APPENDIX S

HOODS BAYOU SLOPE STABILITY ANALYSIS

Project Name: Greens Road from Aldine Westfield to JFK
Project Number: HG0519680
Hoods Bayou
Loading Condition: Short Term
Shear Strength: Undrained



Name: Lean Clay1
Unit Weight: 125 pcf
Cohesion': 1,400 psf

Name: Lean Clay2
Unit Weight: 125 pcf
Cohesion': 1,400 psf
Phi': 0 °

Name: RipRap
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

Name: Concrete Liner
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 01/20/15	APPROVED BY: ND	PREPARED BY: SS

BAYOU GLOBAL STABILITY ANALYSIS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE S-1

SLOPE/W Analysis

File Information

Created By: Sanjeevan Selvaratnam
Last Edited By: Sanjeevan Selvaratnam
Revision Number: 144
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/11/2015
Time: 4:53:57 PM
File Name: ST.gsz
Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Bayou Slope Stability\Final\With Conservative parameters\Revision(08112015)\
Last Solved Date: 8/11/2015
Last Solved Time: 4:54:06 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- Lambda
  - Lambda 1: -1
  - Lambda 2: -0.8
  - Lambda 3: -0.6
  - Lambda 4: -0.4
  - Lambda 5: -0.2
  - Lambda 6: 0

Lambda 7: 0.2
Lambda 8: 0.4
Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: No
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Lean Clay1

Model: Undrained (Phi=0)
Unit Weight: 125 pcf
Cohesion': 1,400 psf
Pore Water Pressure
Piezometric Line: 1

Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 1,400 psf
Phi': 0 °
Phi-B: 0 °
Pore Water Pressure

Piezometric Line: 1

RipRap

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Concrete Liner

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Grid

Upper Left: (33.99289, 110.5768) ft
Lower Left: (33.99289, 82.93938) ft
Lower Right: (104.02479, 82.93938) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (12, 76.23665) ft
Upper Right Coordinate: (26, 76.23665) ft
Lower Left Coordinate: (12, 51.94146) ft
Lower Right Coordinate: (26, 51.94146) ft
Number of Increments: 20
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 77) ft
Right Coordinate: (200, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	0	58
Coordinate 2	200	58

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 50 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	0	82
	36	82

Points

	X (ft)	Y (ft)
Point 1	0	77
Point 2	36.4	77
Point 3	63	67
Point 4	81	59
Point 5	116	67
Point 6	146	77
Point 7	200	77
Point 8	0	67
Point 9	200	67
Point 10	0	50
Point 11	200	50
Point 12	117	67
Point 13	80	59
Point 14	147	77

Point 15	35.4	77
Point 16	62	67
Point 17	45	67
Point 18	79	50
Point 19	83	50
Point 20	134	67
Point 21	53	71.5
Point 22	54	71.5
Point 23	89	58

Regions

	Material	Points	Area (ft²)
Region 1	Concrete Liner	15,2,22,3,4,13,16,21	18
Region 2	RipRap	12,5,6,14	10
Region 3	Lean Clay1	8,1,15,21,16,17	501.85
Region 4	Lean Clay1	12,14,7,9,20	680
Region 5	Lean Clay2	10,8,17,18	1,054
Region 6	Lean Clay2	19,20,9,11	1,555.5
Region 7	Lean Clay2	18,17,16,13,4,23,5,12,20,19	521

Current Slip Surface

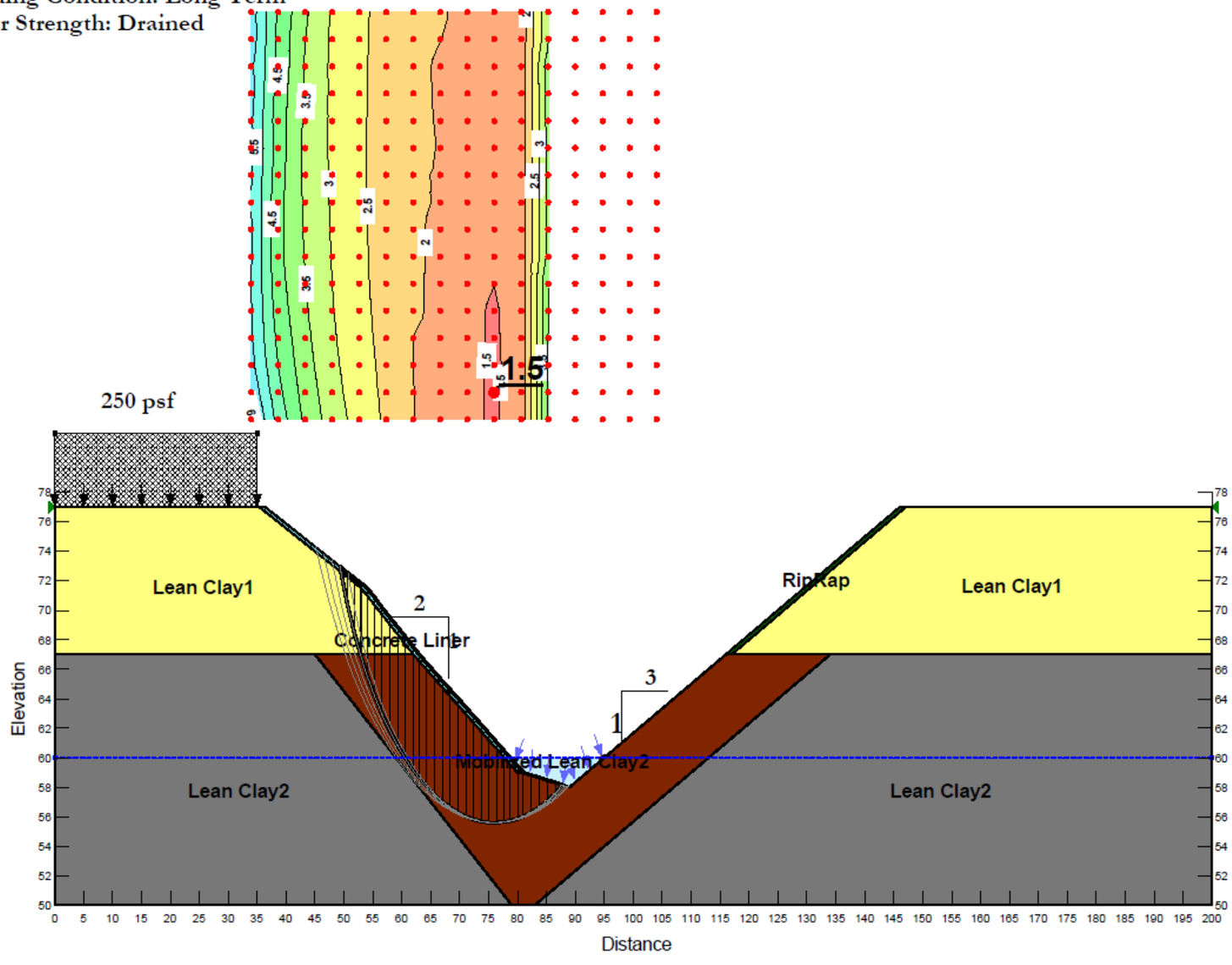
Slip Surface: 4,179
F of S: 3.7
Volume: 892.01124 ft³
Weight: 111,951.41 lbs
Resisting Moment: 5,944,538.1 lbs-ft
Activating Moment: 1,599,859.9 lbs-ft
Resisting Force: 98,252.76 lbs
Activating Force: 26,447.621 lbs
F of S Rank: 1
Exit: (87.089849, 58.238769) ft
Entry: (16.909306, 77) ft
Radius: 53.107856 ft
Center: (62.00565, 105.04932) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	18.250383	75.044351	-1,063.5675	-45.034831	0	1,400
Slice 2	20.932536	71.44935	-839.23945	483.50471	0	1,400
Slice 3	23.614689	68.404999	-649.27192	897.28921	0	1,400
Slice 4	26.261295	65.810729	-487.38951	1,234.1087	0	1,400
Slice 5	28.872354	63.578403	-348.09232	1,518.2219	0	1,400
Slice 6	31.483412	61.617862	-225.7546	1,768.3005	0	1,400
Slice 7	34.094471	59.893421	-118.14947	1,993.1639	0	1,400
Slice 8	35.7	58.915403	-57.121177	2,126.3412	0	1,400
Slice 9	36.2	58.63315	-39.508582	1,937.1615	0	1,400
Slice 10	36.886106	58.260979	-16.285085	1,973.0271	0	1,400
Slice 11	38.643511	57.376992	38.875698	2,036.5314	0	1,400
Slice 12	41.186106	56.212024	111.56968	2,119.6234	0	1,400
Slice 13	43.728702	55.203915	174.47574	2,189.5551	0	1,400
Slice 14	46.333333	54.325797	229.27026	2,247.5555	0	1,400
Slice 15	49	53.576934	275.99935	2,292.5959	0	1,400
Slice 16	51.666667	52.975312	313.54056	2,321.8913	0	1,400
Slice 17	53.5	52.629456	335.12194	2,336.2949	0	1,400

Slice 18	55.333333	52.379417	350.72437	2,307.7386	0	1,400
Slice 19	58	52.109622	367.55958	2,231.2349	0	1,400
Slice 20	60.666667	51.975098	375.95387	2,131.8592	0	1,400
Slice 21	62.5	51.946115	377.76243	2,050.706	0	1,400
Slice 22	64.23382	52.002595	374.23809	1,967.7859	0	1,400
Slice 23	66.701459	52.163974	364.16804	1,839.0664	0	1,400
Slice 24	69.169099	52.441533	346.84834	1,687.4547	0	1,400
Slice 25	71.636739	52.83713	322.1631	1,512.8552	0	1,400
Slice 26	74.058799	53.341702	290.67779	1,319.723	0	1,400
Slice 27	76.435279	53.954251	252.45473	1,109.9212	0	1,400
Slice 28	78.81176	54.686335	206.77273	881.58141	0	1,400
Slice 29	80.5	55.268608	170.43886	705.04663	0	1,400
Slice 30	82.409772	56.041314	122.22198	549.74977	0	1,400
Slice 31	85.229315	57.314131	42.798207	344.7388	0	1,400
Slice 32	86.864468	58.119384	-7.4495884	219.89636	0	1,400

Project Name: Greens Road from Aldine Westfield to JFK
Project Number: HG0519680
Hoods Bayou
Loading Condition: Long Term
Shear Strength: Drained



Name: Lean Clay1
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Lean Clay2
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: RipRap
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

Name: Mobilized Lean Clay2
Unit Weight: 125 pcf
Cohesion': 50 psf
Phi': 22.2 °

Name: Concrete Liner
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

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DATE: 01/20/15	APPROVED BY: ND	PREPARED BY: SS

BAYOU GLOBAL STABILITY ANALYSIS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE S-2

SLOPE/W Analysis

File Information

Created By: Sanjeevan Selvaratnam
Last Edited By: Sanjeevan Selvaratnam
Revision Number: 141
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/11/2015
Time: 5:00:38 PM
File Name: LT.gsz
Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Bayou Slope Stability\Final\With Conservative parameters\Revision(08112015)\
Last Solved Date: 8/11/2015
Last Solved Time: 5:00:47 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
Side Function
Interslice force function option: Half-Sine
Lambda
Lambda 1: -1
Lambda 2: -0.8
Lambda 3: -0.6
Lambda 4: -0.4
Lambda 5: -0.2
Lambda 6: 0

Lambda 7: 0.2
Lambda 8: 0.4
Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: No
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Lean Clay1

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °

Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

RipRap

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Mobilized Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 50 psf
Phi': 22.2 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Concrete Liner

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Grid

Upper Left: (33.99289, 110.5768) ft
Lower Left: (33.99289, 82.93938) ft
Lower Right: (104.02479, 82.93938) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (12, 76.23665) ft
Upper Right Coordinate: (26, 76.23665) ft
Lower Left Coordinate: (12, 51.94146) ft
Lower Right Coordinate: (26, 51.94146) ft

Number of Increments: 20
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 77) ft
Right Coordinate: (200, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	0	60
Coordinate 2	200	60

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 50 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	0	82
	35	82

Points

	X (ft)	Y (ft)
Point 1	0	77
Point 2	36.4	77
Point 3	63	67
Point 4	81	59
Point 5	116	67

Point 6	146	77
Point 7	200	77
Point 8	0	67
Point 9	200	67
Point 10	0	50
Point 11	200	50
Point 12	117	67
Point 13	80	59
Point 14	147	77
Point 15	35.4	77
Point 16	62	67
Point 17	45	67
Point 18	79	50
Point 19	83	50
Point 20	134	67
Point 21	53	71.5
Point 22	54	71.5
Point 23	89	58

Regions

	Material	Points	Area (ft²)
Region 1	Concrete Liner	15,2,22,3,4,13,16,21	18
Region 2	RipRap	12,5,6,14	10
Region 3	Lean Clay1	8,1,15,21,16,17	501.85
Region 4	Lean Clay1	12,14,7,9,20	680
Region 5	Lean Clay2	10,8,17,18	1,054
Region 6	Lean Clay2	19,20,9,11	1,555.5
Region 7	Mobilized Lean Clay2	18,17,16,13,4,23,5,12,20,19	521

Current Slip Surface

Slip Surface: 543
F of S: 1.5
Volume: 214.99551 ft³
Weight: 27,218.997 lbs
Resisting Moment: 373,450.99 lbs-ft
Activating Moment: 256,578.15 lbs-ft

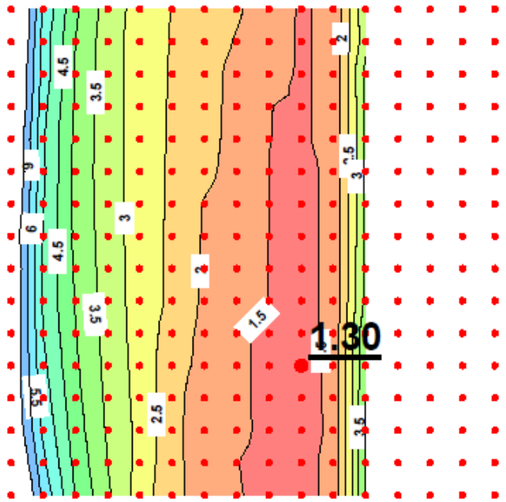
Resisting Force: 10,560.553 lbs
Activating Force: 7,258.9171 lbs
F of S Rank: 1
Exit: (87.93832, 58.13271) ft
Entry: (49.314516, 72.964214) ft
Radius: 29.196136 ft
Center: (76.01203, 84.781875) ft

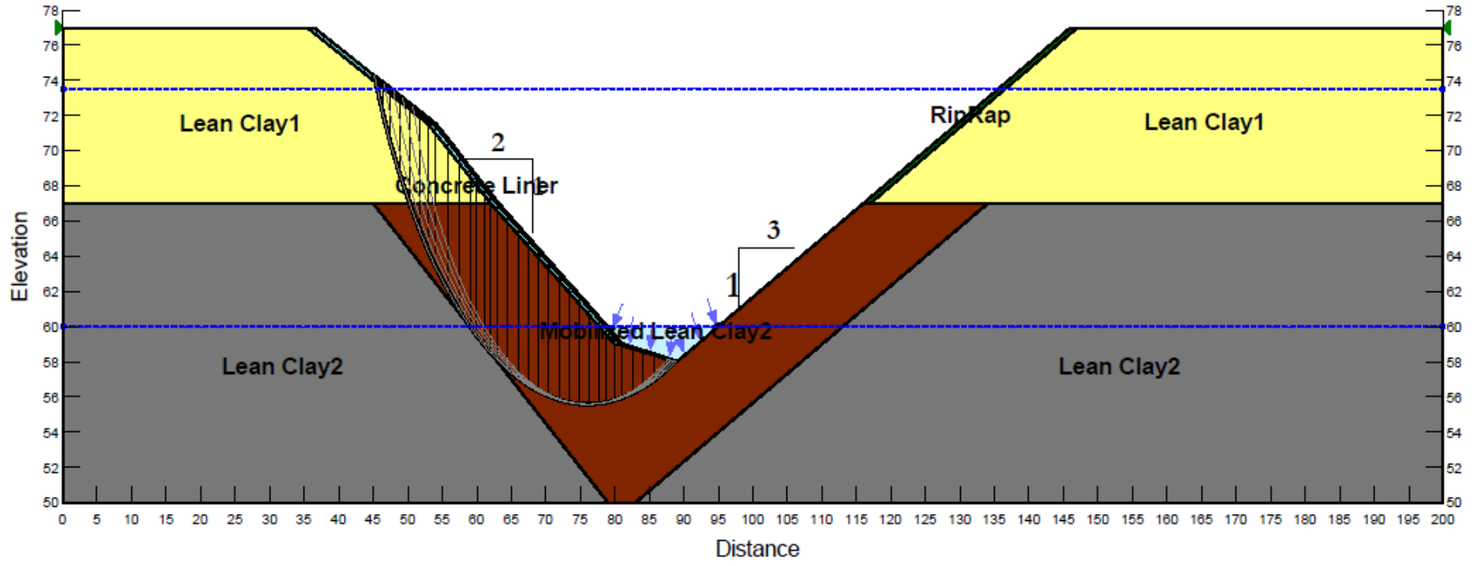
Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	49.396513	72.78234	-797.61799	23.324001	0	0
Slice 2	50.041363	71.499903	-717.59397	-192.53325	-78.571362	350
Slice 3	51.167066	69.485157	-591.87378	-2.7877993	-1.1376798	350
Slice 4	52.292769	67.785486	-485.81432	156.7375	63.963389	350
Slice 5	52.92781	66.906773	-430.98263	420.68497	171.67835	50
Slice 6	53.5	66.207547	-387.35095	474.88371	193.79645	50
Slice 7	54.657593	64.895413	-305.47379	564.47178	230.35667	50
Slice 8	55.97278	63.568093	-222.649	641.78295	261.90677	50
Slice 9	57.287967	62.396861	-149.5641	706.5691	288.34551	50
Slice 10	58.603154	61.358081	-84.744251	760.78253	310.4696	50
Slice 11	59.918341	60.434674	-27.123681	805.75024	328.82058	50
Slice 12	61.287967	59.583934	25.962546	846.14129	334.70874	50
Slice 13	62.5	58.906766	68.21779	875.97858	329.64107	50
Slice 14	63.670455	58.33282	104.03204	899.89258	324.78467	50

Slice 15	65.011364	57.747161	140.57718	923.4257	319.47456	50
Slice 16	66.352273	57.239205	172.27361	938.00398	312.48877	50
Slice 17	67.693182	56.804708	199.38625	943.561	303.69209	50
Slice 18	69.034091	56.44028	222.12651	939.84363	292.89493	50
Slice 19	70.375	56.143241	240.66176	926.46145	279.86967	50
Slice 20	71.715909	55.911505	255.12209	902.93558	264.36779	50
Slice 21	73.056818	55.743505	265.6053	868.74845	246.13816	50
Slice 22	74.397727	55.638136	272.18032	823.39413	224.94619	50
Slice 23	75.738636	55.594719	274.88955	766.428	200.59313	50
Slice 24	77.079545	55.612976	273.75032	697.51308	172.93438	50
Slice 25	78.25	55.675958	269.82021	627.90381	146.13121	50
Slice 26	79.375	55.786894	262.89783	570.98114	125.72647	50
Slice 27	80.5	55.937179	253.52	515.8888	107.07072	50
Slice 28	81.693832	56.152674	240.07314	460.49638	89.953056	50
Slice 29	83.081496	56.463584	220.67239	407.57203	76.272331	50
Slice 30	84.46916	56.846847	196.75677	343.08967	59.71735	50
Slice 31	85.856824	57.305499	168.13683	267.23665	40.441886	50
Slice 32	87.244488	57.843405	134.57154	180.30271	18.662544	50

Project Name: Greens Road from Aldine Westfield to JFK
Project Number: HG0519680
Hoods Bayou
Loading Condition: Rapid Drawdown
Shear Strength: Drained





Name: Lean Clay1
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: Lean Clay2
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °

Name: RipRap
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

Name: Mobilized Lean Clay2
Unit Weight: 125 pcf
Cohesion': 50 psf
Phi': 22.2 °

Name: Concrete Liner
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °

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DATE: 01/20/15	APPROVED BY: ND	PREPARED BY: SS

BAYOU GLOBAL STABILITY ANALYSIS
GREENS ROAD FROM ALDINE WESTFIELD TO JFK
WBS No.: N-000686-0002-3

PROJECT NO.: HG0519680	DRAWING NO.: PLATE S-3

SLOPE/W Analysis

File Information

Created By: Sanjeevan Selvaratnam
Last Edited By: Sanjeevan Selvaratnam
Revision Number: 127
File Version: 8.0
Tool Version: 8.0.10.6504
Date: 8/11/2015
Time: 4:18:23 PM
File Name: RDD.gsz
Directory: G:\HOUSTON\HOU PS\GEO\PROJECTS\2005\HG05-19680 Greens Road, AECOM\Engineering\Bayou Slope Stability\Final\With Conservative parameters\Revision(08112015)\
Last Solved Date: 8/11/2015
Last Solved Time: 4:18:46 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- Lambda
  - Lambda 1: -1
  - Lambda 2: -0.8
  - Lambda 3: -0.6
  - Lambda 4: -0.4
  - Lambda 5: -0.2
  - Lambda 6: 0

Lambda 7: 0.2
Lambda 8: 0.4
Lambda 9: 0.6
Lambda 10: 0.8
Lambda 11: 1
PWP Conditions Source: Piezometric Line
Apply Phreatic Correction: No
Use Staged Rapid Drawdown: Yes
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Grid and Radius
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 30
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 5 ft
Optimization Maximum Iterations: 2,000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Lean Clay1

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 351 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Lean Clay2

Model: Mohr-Coulomb

Unit Weight: 125 pcf
Cohesion': 350 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 351 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

RipRap

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Total Cohesion: 0 psf
Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Mobilized Lean Clay2

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 50 psf
Phi': 22.2 °
Phi-B: 0 °
Total Cohesion: 101 psf
Total Phi: 22.1 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Concrete Liner

Model: Mohr-Coulomb
Unit Weight: 150 pcf
Cohesion': 0 psf
Phi': 0 °
Phi-B: 0 °
Total Cohesion: 0 psf
Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Slip Surface Grid

Upper Left: (33.99289, 110.5768) ft
Lower Left: (33.99289, 82.93938) ft
Lower Right: (104.02479, 82.93938) ft
Grid Horizontal Increment: 15
Grid Vertical Increment: 15
Left Projection Angle: 0 °
Right Projection Angle: 0 °

Slip Surface Radius

Upper Left Coordinate: (12, 76.23665) ft
Upper Right Coordinate: (26, 76.23665) ft
Lower Left Coordinate: (12, 51.94146) ft
Lower Right Coordinate: (26, 51.94146) ft
Number of Increments: 20
Left Projection: No
Left Projection Angle: 135 °
Right Projection: No
Right Projection Angle: 45 °

Slip Surface Limits

Left Coordinate: (0, 77) ft
Right Coordinate: (200, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
Coordinate 1	0	73.53
Coordinate 2	200	73.53

Piezometric Line 2

Coordinates

	X (ft)	Y (ft)
Coordinate 1	0	60
Coordinate 2	200	60

Points

	X (ft)	Y (ft)
Point 1	0	77
Point 2	36.4	77
Point 3	63	67
Point 4	81	59
Point 5	116	67
Point 6	146	77
Point 7	200	77
Point 8	0	67
Point 9	200	67
Point 10	0	50
Point 11	200	50
Point 12	117	67
Point 13	80	59
Point 14	147	77
Point 15	35.4	77
Point 16	62	67
Point 17	45	67
Point 18	79	50
Point 19	83	50
Point 20	134	67
Point 21	53	71.5
Point 22	54	71.5
Point 23	89	58

Regions

	Material	Points	Area (ft^2)
Region 1	Concrete Liner	15,2,22,3,4,13,16,21	18
Region 2	RipRap	12,5,6,14	10
Region 3	Lean Clay1	8,1,15,21,16,17	501.85
Region 4	Lean Clay1	12,14,7,9,20	680
Region 5	Lean Clay2	10,8,17,18	1,054
Region 6	Lean Clay2	19,20,9,11	1,555.5
Region 7	Mobilized Lean Clay2	18,17,16,13,4,23,5,12,20,19	521

Current Slip Surface

Slip Surface: 1,551
F of S: 1.30
Volume: 255.64569 ft³
Weight: 32,332.045 lbs
Resisting Moment: 476,187.96 lbs-ft
Activating Moment: 365,249.33 lbs-ft
Resisting Force: 11,684.417 lbs
Activating Force: 8,960.5314 lbs
F of S Rank: 1
Exit: (88.797557, 58.025305) ft
Entry: (45.230151, 74.240578) ft
Radius: 34.72362 ft
Center: (76.01203, 90.309359) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	45.32936	74.053325	-876.92749	23.385377	0	0
Slice 2	45.520111	73.698036	-854.75746	-271.1699	-110.66239	350
Slice 3	46.057827	72.768095	-796.72915	-191.67855	-78.222566	350
Slice 4	47.004	71.245383	-701.7119	-55.418974	0	322.59586
Slice 5	48.196707	69.556147	-596.3036	121.80297	0	353.80251
Slice 6	49.582121	67.81386	-487.58484	296.70711	0	387.8039
Slice 7	50.956121	66.289326	-392.45393	570.48175	0	248.42822
Slice 8	52.318707	64.94231	-308.40016	683.05985	0	271.28274
Slice 9	53.5	63.880077	-242.11682	771.56182	0	290.1207
Slice 10	54.844802	62.804052	-174.97283	841.20956	0	305.60747
Slice 11	56.534407	61.581145	-98.663474	900.86544	0	318.36034

Slice 12	58.224012	60.504186	-31.461224	945.07833	0	328.76776
Slice 13	59.486414	59.773997	14.102615	970.26346	0	335.48035
Slice 14	60.485881	59.25706	46.359473	983.56234	0	339.72437
Slice 15	61.533874	58.752271	77.858286	993.46244	0	343.61073
Slice 16	62.5	58.327173	104.38442	997.50884	0	346.16139
Slice 17	63.7375	57.837154	134.9616	1,001.523	0	348.68092
Slice 18	65.2125	57.316969	167.42112	1,003.213	0	352.5702
Slice 19	66.6875	56.86991	195.31763	996.11835	0	354.74111
Slice 20	68.1625	56.493069	218.83251	980.15843	0	354.98376
Slice 21	69.6375	56.184115	238.11125	955.62683	292.81268	50
Slice 22	71.1125	55.941213	253.26831	921.89423	272.86118	50
Slice 23	72.5875	55.762968	264.39083	877.77734	250.3184	50
Slice 24	74.0625	55.648379	271.54114	823.07646	225.0774	50
Slice 25	75.5375	55.596816	274.75867	757.59827	197.04319	50
Slice 26	77.0125	55.607997	274.06098	681.17025	166.13821	50
Slice 27	78.25	55.661556	270.71892	609.04819	138.06962	50
Slice 28	79.375	55.754679	264.90805	554.54187	118.19737	50
Slice 29	80.5	55.880683	257.04535	503.36312	100.52042	50
Slice 30	81.779756	56.077241	244.78014	452.84321	84.908965	50

Slice 31	83.339267	56.376999	226.07525	403.22799	72.294694	50
Slice 32	84.898779	56.751873	202.68312	342.35254	56.998036	50
Slice 33	86.45829	57.204421	174.44412	269.96052	38.979522	50
Slice 34	88.017801	57.737889	141.15572	185.35354	0	66.726802

Project Name: Greens Road
Project Number:HG0519680

By: SS Date: 1/25/2015
Check'd By: ND Date 1/25/2015

Lean Clay2 - Effective

Linear Shear Strength Parameter Evaluation (Mesri & Abdel-Ghaffar, 1993)		
Plasticity Index, PI	25	No reduction if PI < 20
Strength Reduction Ratio, η	0.8	From Fig. 13, Mesri & Abdel-Ghaffar, 1993
Effective Peak Friction Angle, φ' (deg)	22.2	From CU Test or Fig. 1 of Mesri-Ghaffar, 1993
Effective Peak Cohesion, c (psf)	350	From CU Test
Maximum Depth of Active Zone, (ft)	8	
Effective Unit Weight, γ', (pcf)	135	
Is $c'_{peak} \geq \sigma'_n (1-\eta) \tan\varphi'_{peak} / \eta$?	YES	
Peak Shear Strength, τ, (psf)	790.7	
c'_{mob} (psf)	191.9	
φ'_{mob} (degrees)	22.2	

Input Parameters
Calculated Parameters

For explanation of the procedure, see attached.